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THE METEOROLOGICAL MAGAZINE

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BLUE SUN AND MOON

By G. A. BULL, B.Sc.

Over much of western Europe between September 26 and 30, 1950 the sun and moon were seen blue in colour.

The first reported observation of the "blue" sun in Europe was made from Bwlchgwyn, near Wrexham, Denbighshire, North Wales at 0615 G.M.T., very soon after sunrise, on the morning of September 26. Bwlchgwyn is 1,200 ft. above M.S.L. and commands a wide clear view of the eastern horizon. The sun was obscured by cloud at Bwlchgwyn soon after this observation was made and was not seen again during the day. Over the western and northern parts of the British Isles there was too much low cloud on the morning of the 26th for the sun to be seen.

After midday, the clouds began to break over Scotland, and the phenomenon was seen from most places in that country. Later in the afternoon it was seen from Wales and western England.

The colour assumed by the sun is variously described from steely grey to deep blue, royal blue or purple. An observer at Glasgow said the sun appeared as it does through the deep blue anti-glare glass used in motor-cars. The brightness of the sun was diminished to such an extent that it could be watched continuously without discomfort. In fact, some persons who telephoned the Meteorological Office in Edinburgh during the afternoon were uncertain whether they were looking at the sun or the moon.

The disc of the sun was quite sharp and there was no sign of corona or halo. The attention of some people was directed to the sun by noticing that the "rays" shining into rooms were blue.

On observing the phenomenon, Mr. F. Bothwell, of the Meteorological Office at Leuchars, Fife, arranged for an aircraft to ascend to report on the change in colour with height. The pilot of the aircraft, F/Lt. West Jones, reported as follows:—

1549 G.M.T.: 31,000 ft: [sun] still blue, entering cloud of brown haze colour.

1554 G.M.T.: 38,000 ft.: nearly through cloud which obscures land, sun normal, colour tinged with blue.

1558 G.M.T.: 43,000 ft.: above cloud, sun normal colour.

The pilot of an aircraft flying near Cambridge at 0715, September 27, reported encountering brown haze with a smell of burnt paper at 30,000–32,000 ft.

The pilots of some aircraft flying the Atlantic made similar observations. Thus, the pilot of aircraft CFTFM reported to Prestwick that he passed through thick smoke between 0500 and 0600 G.M.T. on September 26 at 17,000 ft. in lat. 59°N., long. 35° to 25°W., and had to use instruments because of the poor visibility. A pungent smell suggestive of forest fires came into the aircraft.

The observing officers of s.s. *Manchester Progress* report seeing the sun mauve in colour over the central North Atlantic (59°02'N., 46°13'W.) on September 25 from 1500 to 1515 G.M.T. After the latter time the sun was hidden by cloud.

On the following night, the moon had a green or blue tinge as seen from the British Isles, but the effect was less pronounced than with the sun. Mr. J. Paton writes that the moon as seen from Edinburgh was still bluish at 2330 on the 26th and normal at midnight.

Mr. R. J. Murgatroyd of the Meteorological Office at R.A.F. Headquarters in Germany reports that the sun was seen blue or mauve in colour over the British Occupation Zone in Western Germany from dawn on the 27th until the afternoon. At Gatow, near Berlin, the sun was first seen blue about noon and the moon appeared blue throughout the following night, 27th–28th. From Schwechat (near Vienna) neither sun nor moon appeared blue.

A detailed report on the observations of blue sun at Gibraltar and the Atlantic to westward has been received from Mr. E. A. Ward of the Meteorological Office, Gibraltar. He writes that it was seen at 39° 40'N., 12° 20'W. on the 27th by the pilot of the routine meteorological flight from Gibraltar, following descent to the 950-mb. level. From the 500-mb. level, an hour before, the sun had appeared normal. From Gibraltar itself the blue sun was first seen soon after dawn on September 28 and it retained its blue colour all that day. The colouration was most marked during the forenoon and evening and was faint in the afternoon. Blue sun was also seen on the morning and evening of the 29th and on the morning of the 30th. The sky at Gibraltar had a milky, or at times grey, appearance as though covered with a uniform sheet of high cloud which, owing to the absence of halo phenomena, was at first thought to be thin altostratus. This sheet persisted with occasional changes in density until the afternoon of the 30th when it disappeared and the sun's colour returned to normal.

Mr. D. W. Johnston, of the Meteorological Office, Malta, reports that the sun was visible there on the 27th and 28th but was not blue. On the 29th and 30th the sky was almost continuously overcast but when the sun partially broke through about 1600 G.M.T. on the 29th, the sunshine seemed to be of a faintly bluish tinge.

According to the Press the blue sun was also seen on the 27th from France, Switzerland, Portugal and Scandinavia.

Cause of the optical phenomena.—Canadian newspapers state that extensive forest fires broke out in Alberta some 340 miles north-west of Edmonton during Saturday, September 23. Smoke from these fires travelled eastwards reaching Ontario, some 2,000 miles from the scene of the fire, by the afternoon of Sunday, September 24. Over eastern Canada and the north-eastern United States the smoke clouds were thick enough to blot out the sun and to cause lights to be switched on in buildings and streets. Floodlights had to be turned on to allow baseball games to proceed. The base of the smoke cloud over eastern Canada was estimated at 7,000 ft.

There seems little doubt that the optical phenomena already described were produced by the same smoke.

The observations of a milky haze rather like altostratus as seen from the ground, which appeared as a brown haze to the pilot of the aircraft over Leuchars, and the reports of smoke and mauve sun over the Atlantic support this view.

The upper air charts for the relevant period show that the upper winds over the Atlantic were favourable for carrying the smoke to Europe. A trajectory computed from the charts of the *Daily Aerological Record* using winds at 750 mb. (approximately 8,000 ft.) over eastern Canada, 500 mb. (approx. 18,000 ft.) over the western half of the Atlantic and at 300 mb. (approx. 30,000 ft.) over the eastern half brings the smoke to Scotland by the afternoon of September 26. The heights in the computation were varied to allow for the apparent ascent of the smoke layer as it travelled eastwards.

An intense depression was centred over Labrador on the 24th and 25th and over Davis Strait on the 26th. A broad wedge of high pressure extended northwards from the Azores. Another depression was centred to the east of Greenland. A slow-moving depression which was over the British Isles on the 25th moved eastwards to the North Sea on the 26th. At 1500 on the 26th there was, at the 300-mb. level, a long trough extending from Scandinavia over the Low Countries and France to Spain. The strength of the high-level winds over the Atlantic is shown by the fact that o.w.s. *Weather Observer*, at 59°N., 18·8°W., and roughly on the trajectory of the smoke, measured winds of 299° 62 kt. at 300 mb. at 0300 G.M.T., 281° 66 kt. at 0900 and 291° 90 kt. at 1500 on the 26th. Aldergrove observed a wind of 357° 74 kt. at 1500 on the same day.

The upper air temperatures measured on the 26th over the Atlantic and Great Britain show very dry air at all levels between 900 mb. and 400 mb. as do those measured at Gibraltar from the 27th to the 30th.

As Mr. Ward of Gibraltar has pointed out in correspondence, the upper winds of the 27th and 28th were favourable for rapid movement southwards of the smoke from the British Isles. The wind at 500 mb. over the Bay of Biscay on the 27th was about 020° 50 kt., and at 300 mb. it was about 80 kt. The Gibraltar meteorological reconnaissance flight reported north-easterly winds of 65–80 kt. at 500 mb. to the westward of Portugal. Over Gibraltar itself the upper winds were from SSW. to WSW.

Precisely the same optical phenomena have been seen in the past, notably in the tropics after the explosion of Krakatoa in 1883. A large number of occasions before 1887 of blue or green sun and moon, usually definitely connected with volcanic smoke, are described in Kiessling's large work[1] on twilight and allied phenomena. More recently, reports of the sun being seen blue through duststorms in the United States[2] and Egypt[3] have been published.

A very vivid description by Whymper of a bright green sun seen through smoke from a sudden eruption of the volcano Cotopaxi in the Andes on July 3, 1880 is reported by Kiessling[1]. Kiessling made observations of the sun through various artificially produced smokes including the smokes from sal-ammoniac, burning magnesium, gunpowder and smouldering vegetation. He used an apparatus in which glass vessels were filled with the particular smoke until the sun was only just visible through it. The colour of the sun was at first a brownish red but gradually became first a strong violet and later a brilliant azure blue. Kiessling emphasized that the effect was the same with all the kinds of smoke which he used and says further that the same observation can be made with steam. Minnaert[4] describes seeing the sun blue and green through the steam cloud from a railway engine while Keen[5] describes the similar effect obtained when viewing a source of white light through colloidal sulphur particles.

The optical theory of the " blue " or " green " appearance of the sun is not as yet worked out. Lord Rayleigh showed over 70 years ago that particles small in comparison with the wave-length of the incident radiation give much more intense scattering on the shorter than the longer wave-lengths and so tend to make the sun more red in colour. On the other hand particles large in comparison with the wave-length give neutral scattering, but a cloud of such particles all of the same size produces a corona diffraction system. The angular radius of the brightest ring of the system is inversely proportional to the diameter of the particles and is nearly 3° for particles of radius 0·01 mm. No corona was reported as visible at the same time as the " blue " sun and some observers specifically mention the absence of corona. The optical effects produced by particles of radius between about the wave-length of visible light, which occupies the range of wave-lengths 0·0004 to 0·0007 mm., and 0·002 mm. are not yet thoroughly understood, because the mathematical formulæ given by Mie[6] for the scattering of radiation are unsuited to numerical computation for the scattering of light by such particles, and the simple diffraction theory based on Babinet's principle does not apply to such particles either. Minnaert in his discussion of the blue sun ascribes the phenomenon to particles of the order of magnitude just mentioned.

Note added later.—Dr. H. Wexler, of the United States Weather Bureau, in *Weatherwise*[7] gives much more information on the movement of the smoke and the occurrence of associated optical phenomena over North America.

The forest fires in Alberta were burning during the week commencing September 17 and reached their peak from September 22 to 24. The smoke covered all eastern Canada and the United States, and the sun or moon was seen coloured at Washington, D.C., from September 25 to 27. Detailed computations of the diffusion of the smoke are being made in the Weather Bureau.

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DISTANCE OVER WHICH AN AIRCRAFT FLYING ON A CONSTANT HEADING MAY EXPERIENCE SEVERE ICING IN CONVECTIVE CLOUD

By R. F. JONES, B.A., and J. G. D. BEIMERS

Introduction.—In considering aircraft-icing problems it has long been recognized that the cumulonimbus cloud is the cloud in which, owing to the large amount of free water available in the supercooled state, icing is likely to be most severe. Cumulonimbus clouds, however, are isolated and of varying sizes, and information has been lacking on the frequency with which such clouds and, therefore, potentially severe icing will be encountered on an aircraft flight at a constant heading, and on the length of time an aircraft might be exposed to the risk of continuous severe icing. Answers to both these problems would be of value in assessing the general icing risk to aircraft and would assist in the design of aircraft de-icing equipment.

Recent papers[1,2] have discussed the radar echoes received from precipitating cumulus and cumulonimbus clouds, using a 10-cm. radar equipment. The echoes received from levels above the freezing level have been interpreted as coming from that part of the cloud which contains a large enough concentration of supercooled water drops of raindrop size. Although 10-cm. radar equipment will not therefore define the whole volume of the cloud[3], it will indicate the part of the cloud in which the free water concentration is greatest and therefore the part of the cloud in which the icing may be expected to be most severe. The P.P.I. display of such an equipment gives a projection of the echoing volume of the cloud on a nearly horizontal plane. The horizontal dimensions of a cumulonimbus echo do not vary considerably with height[3] except near to the echo top, nor is the echo column at any time appreciably inclined to the vertical, so that the width of an echo on the P.P.I. display along a particular bearing can with reasonable accuracy be taken to represent the distance over which an aircraft, flying on this bearing above the freezing level and below the echo top, would be exposed to the risk of severe icing.

An analysis of P.P.I. display-tube photographs taken on showery days may therefore give useful data towards the solution of the problems set out in the first paragraph above and this paper gives the results of such an analysis.

Data available and method of analysis.—P.P.I. display-tube photographs, taken at East Hill (near Dunstable, Bedfordshire), are available for many different weather situations and those photographs relating to days with isolated showers were extracted. Days on which the showers appeared to be associated with well marked troughs or cold fronts, leading to a long line of almost continuous echo extending along one bearing only, were not considered.

On each photograph the largest aggregate length of echo intercepted on a straight line through the station (the centre of the photograph) was measured, so that this line gave the heading an aircraft, flying over the station, would take to experience the greatest icing risk at the time the photograph was taken. The line covered a total range of 120 miles with the station at its centre, but, to exclude errors due to permanent echoes and observations made at excessively short ranges, all echoes lying within 10 miles of the station were ignored, leaving a total length of 100 miles to be examined. In addition the longest distance continuously within echo on this bearing was also measured.

Facing p. 8 are typical examples of the photographs used and measurements made.

A total of 290 photographs taken on 39 days in the period May 13, 1947, to May 17, 1949, inclusive, was analysed in this way. The number of photographs taken on any one day was not the same, but, as the number of individual days was so small and the choice of a representative picture for a particular day impossible, all the available photographs, taken at intervals of not less than five minutes, have been used in the analysis. The maximum readings for each day have been extracted and are set out in Table I. It should be remembered that photographs may not have been taken at the most favourable time on every day, so that the value of the information in Table I is limited.

TABLE I—FREQUENCY OF VARIOUS MAXIMUM ECHO DISTANCES

	Maximum extent of echo (miles)							
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	Total
	number of occurrences							
Total echo	1	7	11	10	5	3	2	39
Continuous echo	1	8	18	9	1	1	1	39

Results of the analysis.—The information, obtained as described above, from all the 290 photographs is presented in Figs. 1 and 2.

Fig. 1 shows the percentage number of occasions when specified values of aggregate distance within echo would have been exceeded on a flight of 100 miles across the station, while Fig. 2 shows the percentage frequency with which, during a 100-mile flight, specified maximum distances of continuous flight within an echo would have been exceeded.

Interpretation and discussion of the results.—On the assumption that flight in the echo part of a cloud (above the freezing level) is associated with severe icing, Fig. 1 may be interpreted as showing the frequency with which severe icing may be expected to last for more than a specified distance in 100 miles of flight in showery conditions above the freezing level, if the flights are chosen so as to give the greatest proportion of possible severe icing at the time of flight.

It will be seen that the maximum frequency occurs at about eight miles (where the slope of the curve is greatest), but the mean value is 10·5 miles and 57 per cent. of all flights would be likely to experience severe icing over an aggregate distance greater than eight miles in 100 miles and one flight in ten may get severe icing for 17 miles or more.

Fig. 2 indicates that the greatest distance on a particular flight over which continuous icing is likely to occur is most frequently five miles (for which value the slope of the curve is greatest), but the mean value is 8·3 miles and 70 per cent. of all flights would experience continuous icing for more than five miles and one flight in ten would be liable to get continuous icing for about 13 miles or more.

It would appear from Fig. 1 that icing for more than about 25 miles (aggregate) in 100 miles is very unlikely but it should be remembered that this is true only for isolated-shower conditions such as occur, for example, in polar air in summer in the east and south-east of England. On some occasions, however, large masses of thunderstorms and areas of thundery rain move in a northerly direction from the continent across England and in such conditions it would not be unlikely for there to be more than 30 miles of continuous echo along a straight line, with the virtual certainty of severe icing above the freezing level. The freezing level in such conditions, however, is usually high and flight in the British Isles beneath the freezing level would not be impossible. On other occasions, associated with cold fronts or well marked polar troughs, long lines of echo may also occur exceeding 30 miles in length but in such conditions the belt of echo is likely to be relatively narrow and the position and orientation of the belt can probably be forecast with reasonable accuracy. Further examination of the single occasion measured when the distance in continuous echo was 32 miles revealed it to be associated with storms moving north from the continent, the freezing level being about 12,000 ft. An occasion of 28 miles of continuous echo, on the other hand, was associated with polar air moving around a depression over Lancashire and the freezing level was at about 5,000 ft.

Comparison between Figs. 1 and 2 reveals that by far the greater proportion of the total echo on a single flight of 100 miles is likely to be contributed by one single continuous echo. Thus, while from Fig. 1, 40 per cent. of all flights would be through more than 10 miles of echo, Fig. 2 indicates that for the same percentage of flights there would be more than 8 miles of continuous echo. Similar results are to be observed for other values of the percentage of flights.

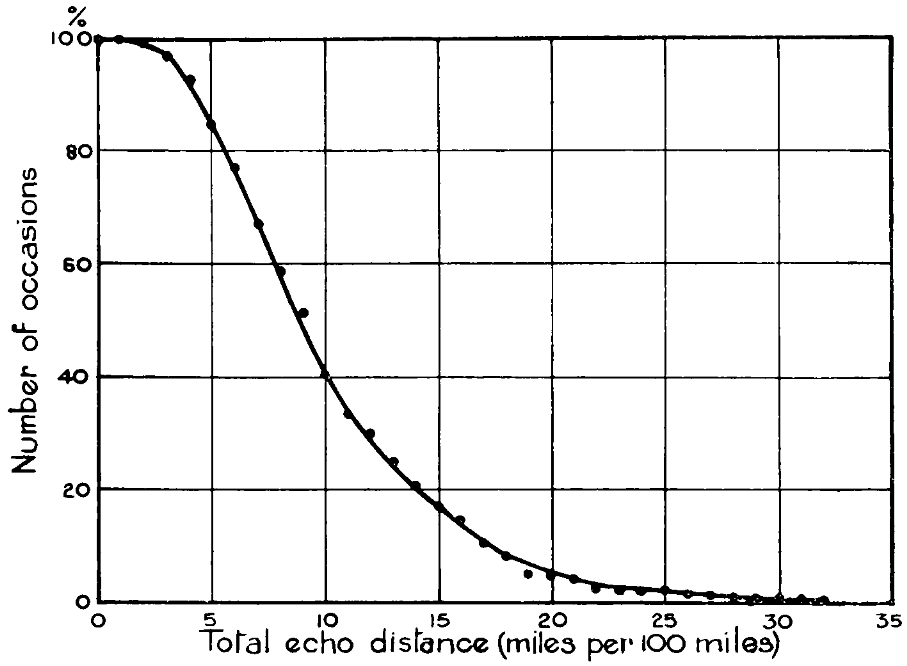


FIG. 1—PERCENTAGE NUMBER OF OCCASIONS WHEN A GIVEN AGGREGATE DISTANCE IN ECHO WOULD HAVE BEEN EXCEEDED ON A 100-MILE FLIGHT

Table I indicates that, by taking only the extreme values for each day of the 39 days, there are 28 days out of the 39 when the distance of severe icing could have been between 5 and 19 miles in 100 miles, the mean distance for all days being 16 miles, and 35 days out of the 39 when the maximum continuous icing could lie between these limits, the mean value being 13 miles. As mentioned previously, however, it cannot be assumed that the worst conditions of each day were photographed on the display tube.

Limitations to the application of the results.—While it is probable that the results here described give some information which has not previously been available and give a general indication of the extent of the icing hazards in cumulonimbus flying, only limited use of the detailed results and values quoted should be made, for the following reasons:—

(i) The analysis covers a period of only two years during which the frequency of occurrence, and severity when it did occur, of shower activity may have been less than the long-term average.

(ii) The analysis is only strictly applicable to a limited area of eastern England and may not apply to other areas, even of England. In particular the results may not be applicable to coastal areas where the shower frequency is high in winter nor to mountainous regions where orographic effects are added to the normal surface-heating effect.

(iii) The analysis does not include frontal effects, including the effect of well marked troughs, which can usually be forecast, but applies to the random distribution of shower activity in unstable air.

(iv) No allowance is made in the measurements for the effect of the range at which the radar echoes were observed. Distant echoes, due to attenuation by range, may appear smaller on the P.P.I. display tube than an echo due to a similar cloud at shorter ranges. Without a detailed knowledge of the way the raindrop distribution varies horizontally through the particular cloud no useful correction can be made for range. In general, however, the nature of the cumulonimbus echo, which indicates the probability of an abrupt change in echo intensity on entering the precipitation core of the cloud, makes it unlikely that any serious correction would be necessary for the majority of echoes examined. In any case the echo observed would still be the volume of maximum icing risk within the cloud at whatever range it was viewed.

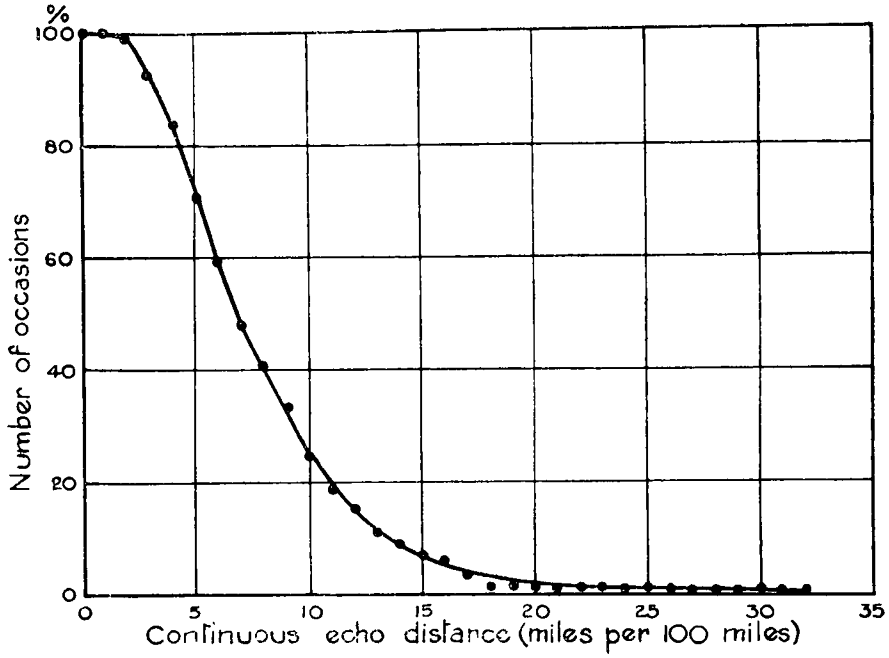
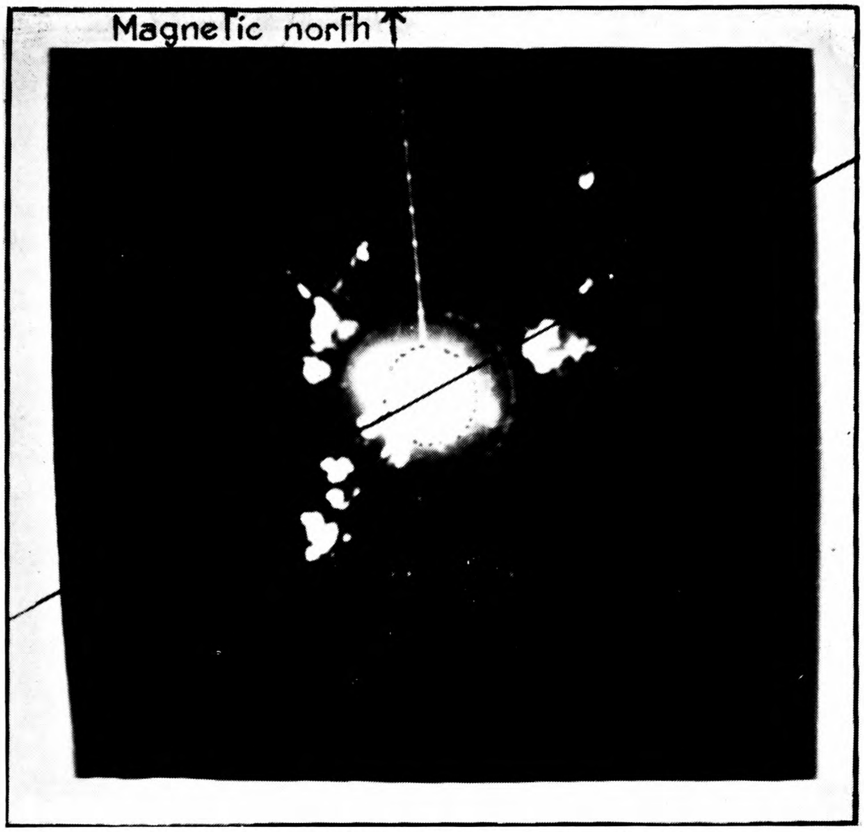
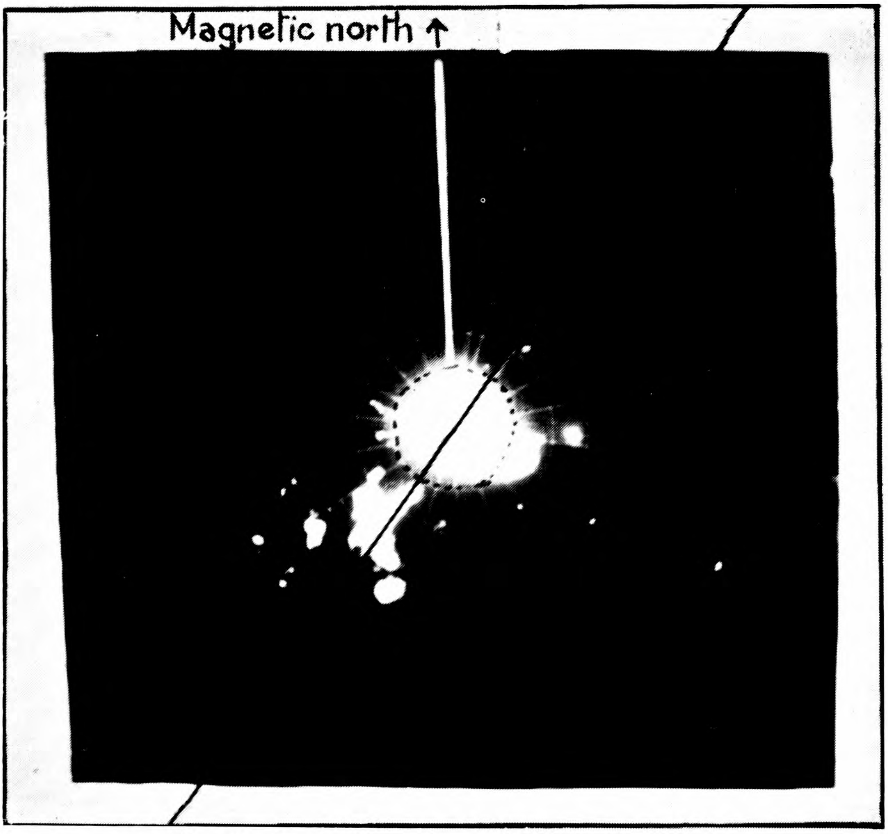


FIG. 2—PERCENTAGE NUMBER OF OCCASIONS WHEN AN AIRCRAFT WOULD HAVE BEEN CONTINUOUSLY IN ECHO FOR MORE THAN GIVEN DISTANCES ON A 100-MILE FLIGHT

(v) The echo as seen on the P.P.I. display, being the projection of the whole volume of echo on an almost horizontal plane, may on some occasions overestimate the extent of the echo at the line of flight above the freezing level.


Magnetic north ↑

10 miles of echo — 7 miles continuous — along the line shown (excluding inner 10 miles)

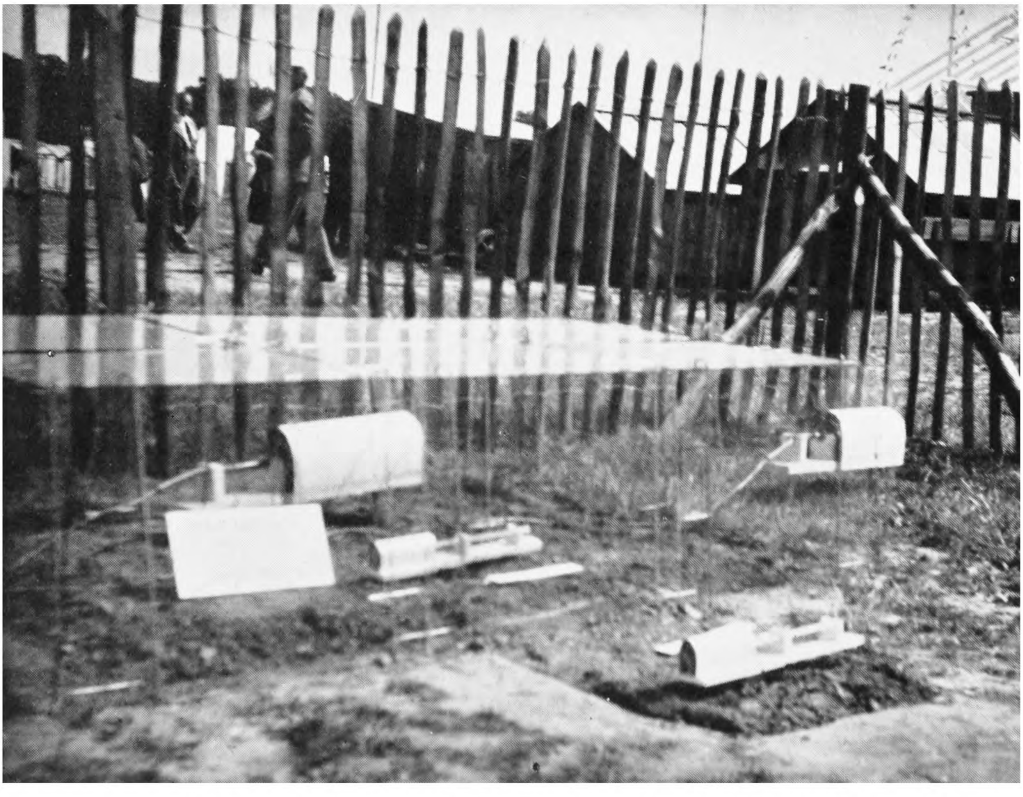

Magnetic north ↑

14 miles of echo — all continuous — along the line shown (excluding inner 10 miles)

RADAR ECHOES FROM CUMULONIMBUS CLOUD (see p. 4)

METEOROLOGICAL OFFICE

GENERAL VIEW OF THE METEOROLOGICAL TENT AND ENCLOSURE AT THE MARKET PRODUCE SHOW, SOUTHAMPTON, JUNE 1950
(Left to right : R. W. Gloyne, G. Williams, R. G. Pyke, L. P. Smith)



MARKET PRODUCE SHOW, SOUTHAMPTON, JUNE 1950: DEMONSTRATION OF THE EFFECT OF CLOCHES ON TEMPERATURE
Thermographs and minimum thermometers are shown inside and outside the cloche. A soil thermometer can also be seen inside the cloche. (See p. 23)

Summary.—An analysis of the radar-echo distribution from showers, as seen on the P.P.I. display of a 10-cm. radar equipment, is used to give an indication of the frequency with which severe icing conditions may be encountered on a flight at a constant heading on a day when isolated showers are occurring.

Undue weight cannot be attached to the detailed results but it would appear that in showery weather severe icing conditions may occur at the worst on about 40 per cent. of all flights in parts of eastern England for more than 10 miles in 100 miles but on only about 4 per cent. of all flights for more than 20 miles in 100 miles. Continuous icing is likely to occur at the worst on about 40 per cent. of all flights for more than 8 miles in 100 miles but on only about 4 per cent. of all flights for more than 17 miles in 100 miles.

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FOG AT LONDON AIRPORT

By N. E. DAVIS, M.A.

London Airport has been operating over four years and sufficient observations are now available to allow for a preliminary appreciation to be made of the visibility—the chief factor affecting operations there. In this note only visibilities less than 1,100 yd. are considered, i.e. only cases of fog.

Fog at London Airport may be ascribed to three factors: radiation, advection and smoke. True advection fog is not a common occurrence at London Airport and will be neglected in the following analysis.

The visibilities reported at each hour of each day for the four years, August 1946 to July 1950, were examined and a record was made of the number of occasions when the visibility was less than (*a*) 220 yd., (*b*) 440 yd., (*c*) 880 yd. and (*d*) 1,100 yd. These figures were grouped according to hours and months and are reproduced in Table I. Each figure in this table gives the number of times in four years when the visibility was less than the prescribed value for every hour of the day for each month. The last two columns give the total number of hours of fog per month for the four years and the mean for a year respectively.

Considering only the mean number of hours of fog per month given in the last column, it is seen that there is a great difference in fog frequency between the six months April to September and the six months October to March. Further the frequency of fog in November during these four years was about 50 per cent. greater than in the other winter months, and the frequency of thick fog (visibility less than 220 yd.) was twice as frequent in November as in October, December and January and three times as frequent as in February and March.

The figures given in the tables for the number of cases of fog and thick fog are reproduced in Figs. 1 and 2 where the isopleths give the percentage

TABLE I—DIURNAL VARIATION OF FOG AT LONDON AIRPORT

Summer months

Time	APRIL				MAY				JUNE				JULY				AUGUST				SEPTEMBER			
	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.
G.M.T.	*number of occasions in four years*																							
0000	...	...	...	3	...	...	1	3	...	...	1	1	...	...	...	...	...	...	...	2	...	1	1	3
0100	...	...	1	3	1	1	2	3	1	1	1	1	1	1	1	1	...	1	1	2	2	2	3	7
0200	...	1	3	4	2	2	4	4	1	1	2	2	...	...	1	1	...	1	1	2	3	3	4	5
0300	...	1	3	4	3	3	6	6	1	1	1	2	...	...	...	1	2	3	5	5	3	4	9	9
0400	1	1	3	5	4	4	5	5	1	2	3	3	1	1	3	3	4	4	4	6	2	4	9	10
0500	1	1	3	5	4	5	5	6	2	2	2	2	1	1	2	2	3	3	5	8	4	6	8	10
0600	2	2	4	6	3	3	4	5	2	4	4	4	...	...	1	1	3	7	8	9	6	8	13	15
0700	1	1	2	6	2	3	3	5	1	1	1	1	...	...	...	...	3	3	5	8	3	6	9	13
0800	1	1	2	3	...	1	1	3	...	1	1	1	...	...	...	...	1	1	2	3	3	3	5	8
0900	...	...	1	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	2
1000	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1100	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
1200	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1300	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1400	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1500	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1600	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1700	...	...	1	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1800	...	...	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1
1900	...	...	...	1	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2000	...	...	...	1	...	...	1	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2100	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
2300	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1
Total	6	8	26	52	19	22	33	50	9	13	16	17	3	3	8	9	16	23	31	47	26	38	63	85
Mean (hr./month)	1	2	7	13	5	6	8	13	2	3	4	4	1	1	2	2	4	6	8	12	7	9	16	21

TABLE I—*continued*

Winter months

Time	OCTOBER				NOVEMBER				DECEMBER				JANUARY				FEBRUARY				MARCH			
	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.
G.M.T.	*number of occasions in four years*																							
0000	3	9	19	23	12	19	24	28	9	12	15	15	6	8	12	18	3	5	11	15	3	7	12	16
0100	7	14	21	23	13	16	23	27	8	9	13	17	9	13	19	20	5	8	14	18	5	5	10	17
0200	7	14	21	29	12	13	21	25	7	10	13	14	7	8	12	17	5	5	11	15	5	5	11	17
0300	10	15	20	29	14	15	21	24	7	10	13	14	8	10	12	13	5	7	12	15	4	7	13	17
0400	13	16	20	26	15	18	21	24	5	6	10	12	7	9	10	12	4	7	12	15	5	6	9	12
0500	15	17	24	29	14	18	20	23	6	6	8	11	6	7	10	10	4	7	12	14	5	6	9	12
0600	15	19	24	28	12	15	21	25	5	5	7	9	8	9	12	12	5	8	14	14	7	10	12	17
0700	16	20	24	27	18	21	26	28	6	6	7	9	6	8	14	15	6	9	16	19	9	12	17	22
0800	15	18	27	33	17	23	29	29	5	6	12	14	9	13	18	18	6	10	19	22	11	12	23	26
0900	9	13	21	29	15	18	27	30	6	7	13	17	9	10	18	22	8	14	18	24	9	11	19	21
1000	5	7	17	20	15	16	26	28	8	8	13	19	8	10	15	21	2	6	16	20	4	5	12	18
1100	2	4	9	15	12	15	23	26	5	5	14	17	6	10	12	18	2	3	11	17	2	5	8	11
1200	...	1	4	7	7	9	15	19	5	5	12	14	5	6	12	18	1	3	9	12	1	1	7	10
1300	...	...	...	...	6	8	11	16	5	5	10	13	4	5	8	11	...	2	9	10	1	1	6	9
1400	...	...	...	...	6	9	13	16	5	5	12	13	4	4	6	10	...	2	5	8	1	1	4	6
1500	...	...	...	2	7	8	13	14	3	5	11	12	4	4	5	7	...	1	5	7	2	2	3	6
1600	...	...	2	3	10	10	11	15	4	6	15	18	2	3	6	14	...	1	3	4	2	2	5	6
1700	...	1	2	4	10	10	14	18	5	6	18	20	3	4	11	17	1	2	5	9	2	2	8	8
1800	...	1	5	9	8	9	17	22	5	9	18	25	4	5	12	18	2	3	9	11	1	5	6	10
1900	...	1	9	10	7	9	20	22	7	9	16	22	5	6	14	21	2	7	12	15	1	3	11	12
2000	1	3	10	14	6	10	20	24	6	8	16	22	5	7	14	17	1	5	12	16	1	4	10	11
2100	2	3	12	18	8	15	23	27	7	8	14	21	4	8	14	18	2	5	14	20	3	4	11	13
2200	2	2	12	20	9	18	25	29	6	7	15	20	4	7	16	17	3	5	15	18	5	7	13	14
2300	2	6	15	21	13	19	24	30	6	7	12	16	6	8	14	16	3	6	13	17	4	5	11	14
Total	124	184	318	419	266	341	488	569	141	170	307	384	139	182	296	380	70	131	277	355	93	128	250	325
Mean (hr./month)	31	46	79	105	67	85	122	142	35	43	77	96	35	45	74	95	17	33	69	89	23	32	63	81

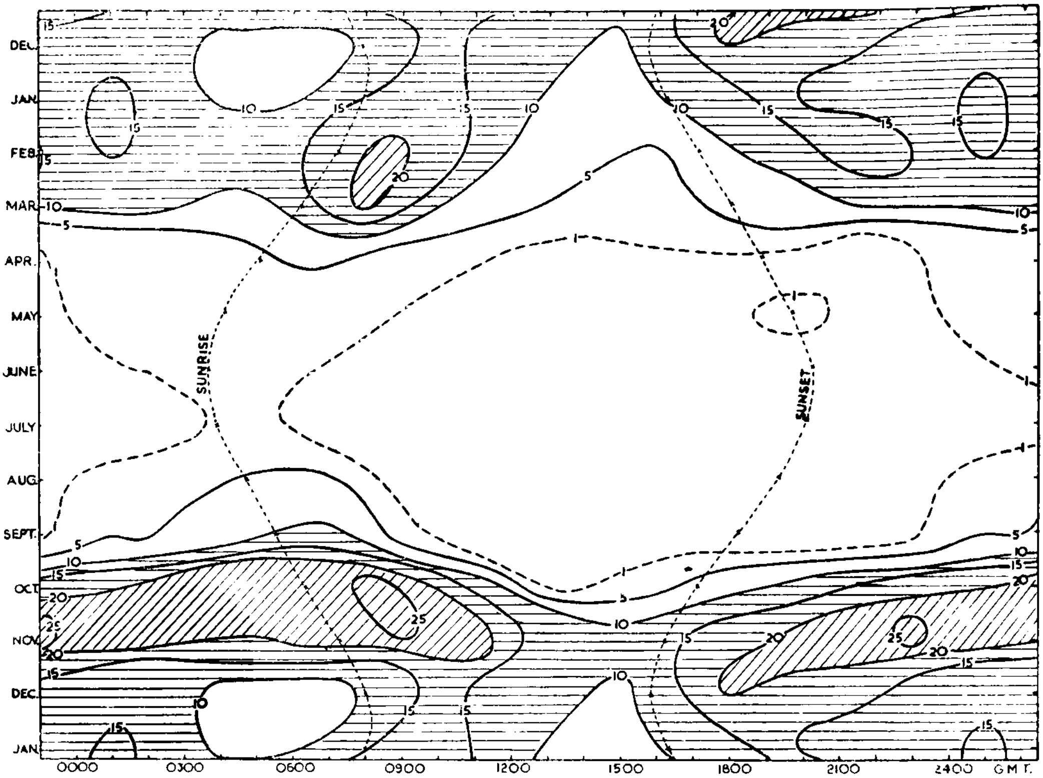

FIG. 1—DIURNAL VARIATION OF FOG AT LONDON AIRPORT

frequency of fog and thick fog respectively. Fig. 1 may be compared with a similar diagram for frequency of mist at Mildenhall given by Durst.*

The salient points in the variation of fog at London Airport to be deduced from these figures may be listed as follows:—

(i) The rapid increase in fog frequency from September to October and November.

(ii) The high frequency of fog and thick fog in the mornings in October and its rapid clearance about four hours after sunrise.

(iii) The high frequency of fog and thick fog in November and its tendency to persist throughout the day.

(iv) The relatively low frequency of fog in the early hours in December and January.

(v) The high frequency of fog in December two to three hours after sunset and to a less extent in January and February.

(vi) The gradually increasing tendency from December to March of the fog to clear in the afternoon.

(vii) The high frequency of fog about two hours after sunrise in February and March.

(viii) The rapid decrease in fog from March to April.

These variations are to be explained by consideration of the length of night (or length of time outgoing radiation is in excess of incoming radiation), the elevation of the sun at midday, the amount of moisture available, the amount of smoke pollution and the general synoptic situation prevailing during the month.

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*DURST, C. S.; Meteorology of airfields, London, 1949.

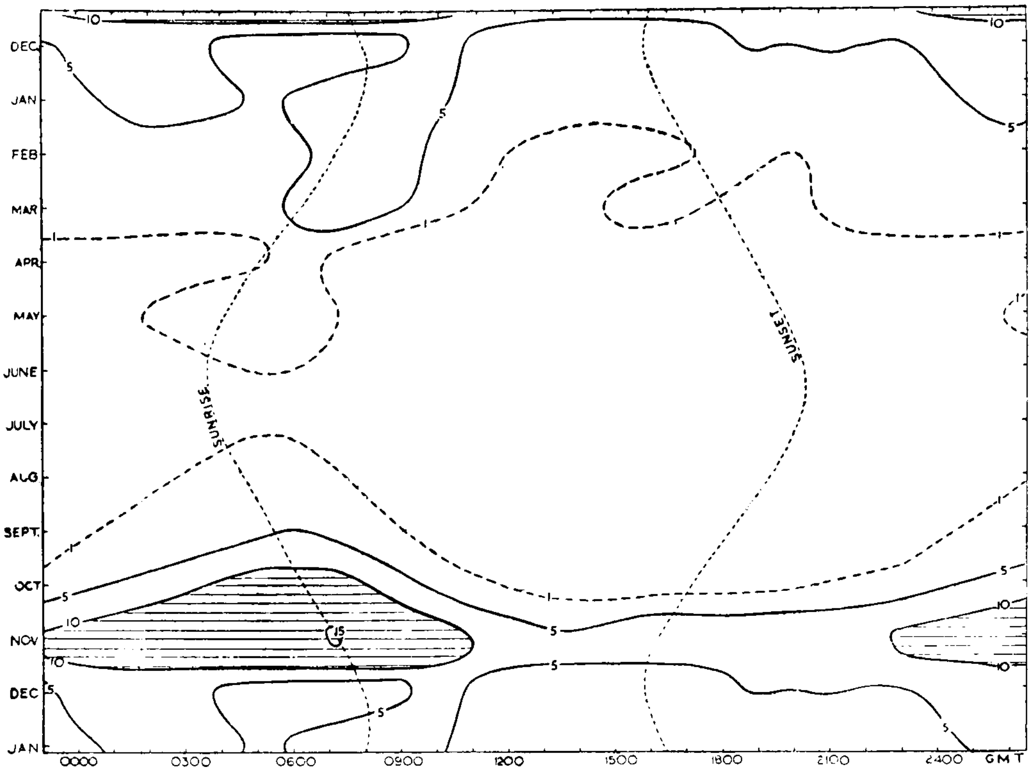

FIG. 2—DIURNAL VARIATION OF THICK FOG AT LONDON AIRPORT

The length of night appears to be crucial in the formation of fog in that fog is far more likely when the length of night is greater than the length of day. Further, when in winter the sun's elevation is small, the amount of incoming radiation is small and is largely reflected from the upper surface of a fog layer. This is particularly the case if the fog is thick or smoky. Winter fog is therefore very slow to clear by day and may not clear at all.

The mean vapour pressure at Kew for the winter months is as follows:—

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
			millibars			
Mean vapour pressure	10·1	8·3	7·1	6·8	6·8	7·1

Vapour pressure is greater in October and November than it is in the other months and hence the formation of thick fog is more likely in October and November than in the others.

The amount of smoke pollution depends on three factors: the time of the day and of the year, the amount of convection, and the direction of the surface wind. The chief cause of smoke pollution in the London area is the domestic fires. These are alight from between 0700 and 0800 to about 2200 during the months November to March and also in the afternoons and evenings in the months October and April. If the air is stable, the smoke will tend to be retained near the ground and smoke pollution will be a maximum in the evening from about 1900 to 2200. After 2200, though stability will continue to increase, little smoke is poured into the atmosphere, while a considerable quantity will fall out. Smoke pollution is therefore a minimum in the early hours during the winter months. In the afternoons, decreasing stability may tend to carry some of the smoke away and there is a secondary minimum about 1500. However, if the concentration of smoke is heavy, radiation from the sun is cut off, and, in the depth of winter when the sun's elevation is low, not sufficient radiation penetrates the smoke to start up convection, so that the smoke may remain near the ground. Further, outgoing radiation is also to some extent restricted so that in a very smoky atmosphere the formation of thick fog may be retarded or even prohibited.

The direction of the surface wind is important in that London Airport lies in the London smoke drift with NE. to ESE. winds. Whenever the surface wind is from this sector visibility will be impaired by smoke. The surface wind is the deciding factor not the gradient wind, as, if the smoke is to produce a marked deterioration of visibility, it must remain near the ground and will therefore move in the direction of the surface wind not that at 2,000 ft. If the wind from between NE. and ESE. is very light, visibility at London Airport will tend to improve during the night as the smoke falls out and the deterioration that normally takes place after sunrise may be delayed until the increased smoke that results from the lighting of the domestic fire has drifted out to the airport.

The effect of the general synoptic situation prevailing during the month is assessed by considering the mean wind speed. Mean wind speeds at Kew for the six winter months are given in the first line of the following table:—

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
			miles per hour			
Long period average	6·7	7·6	8·4	8·2	8·7	8·9
4-yr. period average	6·7	8·0	9·1	9·2	10·4	9·3

The mean speeds for the months October and November are less than for the other months and it may be concluded that synoptic situations favouring fog development are more frequent in October and November than in the other winter months.

The second line of the table gives the mean wind speeds at Kew averaged over the four-year period August 1946 to July 1950. The four-year mean is close to the average for the months October, November and March, but rather above for the months December, January and considerably above for February. The number of cases of fog in these three months is probably somewhat underestimated, especially in the number of cases of thick fog in February. Any adjustment for this, however, would leave the salient features indicated in Figs. 1 and 2 unchanged and these must be regarded as significant variations in fog at London Airport, to be explained by the considerations given above.

From the aircraft operator's point of view, the worst time to plan operations is the period one or two hours after sunrise at all times of the year. In June, July and August there is very little fog at any other time, but in the other months of the summer half-year, April, May and September, some fog occurs for several hours in the early morning before the normal time of maximum occurrence. In the winter half-year the period 2–3 hours after sunset tends to be rather worse than the rest of the night but it is not generally as bad as the period one to two hours after sunrise. In the winter, the best time is 1–2 hours before sunset and, except in October and November, 2–3 hours before sunrise.

METEOROLOGICAL OFFICE DISCUSSION

Thunderstorm electrification

The second Meteorological Office discussion of the present session was held on November 13, 1950. It was opened by Dr. G. D. Robinson who presenced an abstract of three papers by Ross Gunn on thunderstorm electrification:—

> The free electrical charge on thunderstorm rain and its relation to droplet size. *J. Geophys. Res., Baltimore, Md.*, **54**, 1949, p. 57.
>
> The electrical charge on precipitation at various altitudes and its relation to thunderstorms. *Phys. Rev., Lancaster, Pa.*, **71**, 1947, p. 181.
>
> The free electrical charge on precipitation inside an active thunderstorm. *J. Geophys. Res., Baltimore Md.*, **55**, 1950, p. 171.

Discussion was invited on any aspect of the electrification of thunderstorms.

Gunn's observations were incidental to work in connexion with the United States Army–Navy Precipitation Static Project* which required much flying in rain clouds and thunderstorms. The main airborne instruments were generating voltmeters above and below the fuselage and an " induction probe" for measuring the charge on individual precipitation particles. The drops passed through a screened conducting loop and the resulting voltage pulses were amplified and recorded.

In the first paper the maximum charge on a raindrop is established theoretically, the limit being set by the field at the surface which must be less than the dielectric-breakdown strength of air. The reduction of the maximum charge due to deformation of the drops, and to the presence of small cloud particles, polarized in the field of the larger drop, is considered. Simultaneous measurement, in three thunderstorms, of the masses and charges of raindrops at the ground are shown to be in accordance with these predictions, and the result of previous investigators that it is usual for positive and negative drops to be present together is confirmed.

The second paper describes measurements made from aircraft in the cloud system of a weak cold front. Drop charge and field strength measurements are made at various heights from 4,000 to 26,000 ft. (freezing level, 11,500 ft.). The total space charge on precipitation elements is evaluated and compared with the observed fields. It is concluded that the precipitation charge must, to a considerable degree, be neutralized by a charge of opposite sign, either ionic or on the cloud particles.

The third paper extends the work of the second paper to an active thunderstorm in which horizontal traverses were made at various heights between 5,000 and 20,000 ft. (freezing level, 14,000 ft.). The results are generally similar to those in the cold front, the droplet charges being so large that the field at their surface approaches the dielectric-breakdown strength. The maximum electrification is observed at 7,500 ft. at a temperature of +10°C. The distribution of charge in the cloud is apparently complicated. There are large volumes in which all droplets are charged with the same sign.

Gunn does not give detailed measurement of the field strengths, but mentions that fields of 2,000 v./cm. were observed several times in the near vicinity of lightning discharges, and that on an occasion in another storm, when the aircraft was struck, the maximum measured field (assumed vertical) was 1,600 v./cm.

Proc. Inst. Radio Engrs, New York, N.Y.*, **34, 1946, pp. 156 and 234.

Gunn concludes that the particle electrification processes, even in quiet frontal rain area, are sufficient to give an appreciable fraction of the maximum permissible charge, and in this respect they must differ little from those in an active thunderstorm. In an active thunderstorm there are regions, perhaps 2 Km. across, in which all drops carry the same sign of charge, and, if the droplet charge alone is considered, the field at the extremities of these regions should be about 10,000 v./cm., or five times the maximum observed. There must therefore be a compensating charge on the cloud particles even in active thunderstorms. Gunn implies that the electrical difference between ordinary rain and thunderstorms is brought about by the partial separation by strong vertical wind of the precipitation particles and the compensating charge on the cloud particle.

Dr. J. A. Chalmers of the University of Durham, who opened the general discussion, mentioned the theories put forward by Frenkel and by Findeisen to account for the electrification of cloud and precipitation particles. Gunn's observation that the upper positive charge in the cloud was on precipitation particles could not easily be explained on Frenkel's theory. Dr. Chalmers then referred to some measurements which he had made, in collaboration with Dr. Hutchinson, of the charge on single drops at the ground and its relation to the field at the ground and the point-discharge current. This work suggested that the charge on drops at the surface was controlled by the Wilson mechanism operating in the lowest few hundred metres in the plentiful ion supply produced by point discharge.

Dr. T. W. Wormell then spoke of two recent, and as yet unpublished, investigations at Cambridge:—

Mr. L. G. Smith has been studying the electrical charges on individual raindrops at the ground and has devised a method whereby, for each drop falling into the receiver, electric charge, rate of fall, and, also an independent measure of the mass are all displayed on a cathode-ray oscilloscope and recorded photographically. The point-discharge current from a metal point is simultaneously recorded, the two records being synchronized. He has thus been able to obtain a rapid sample of the properties of the rain while conditions might be presumed to be reasonably constant.

When an intense electric field exists at the ground and conditions are fairly steady, the results show clearly the effect of the capture of ions by the drops as they fall from the cloud to the ground in that the smaller drops, which spend a longer time on the descent, tend to have a charge whose sign is the reverse of the sign of the potential gradient while the larger drops tend to have the same sign as the potential gradient. There remains, however, despite the rapid sampling, a very wide spread in the values of the charges on individual drops of the same size. Two drops of sensibly the same size, which fall into the receiver almost simultaneously, may have charges of quite different magnitudes and even of different signs. It would appear to be extremely difficult to account for these differences in terms of a difference in the charges possessed by the drops when they fell from the cloud base and one is left with the puzzling problem as to how the subsequent history of the drops could have differed.

Mr. I. C. Browne has been investigating by radar the vertical structure of overhead thunderstorms, using a narrow vertical beam of radiation, of wavelength 3·2 cm., and displaying the intensity of the echo, scattered from different heights, as a function of height. In several storms an extremely intense echo was observed from a region of limited vertical extent near the base of the cloud, the intensity of the scattered signal increasing exponentially from the top to the base of the region. The condition persisted for several minutes and was accompanied by very heavy rain at the ground. In one particular case, for example, the region extended from 4,000 ft. to 2,700 ft., the echo from the latter height being about 50 times as strong as from the former; the freezing level, on this occasion, was at about 8,000 ft.

A possible explanation of these results would seem to be that large drops are falling into the top of the region and are increasing in number by a repeated process of breaking and regrowth, to the critical size, through the sweeping up of cloud particles. To explain, however, the very rapid increase of scattering power with decreasing height it is necessary to postulate an up-draught whose intensity, in the particular case already quoted, must be about 90 per cent. of the rate of fall of the large drops.

If this be the true interpretation, a region of the cloud has been identified in which the Simpson breaking-drop process is actively at work, and under which a positive gradient of potential would be expected to occur. Clear examples of this type of echo were observed in three different overhead storms during the summer of 1950. In two of the three cases there was, at the time, a strong positive potential gradient; on the third occasion close lightning discharges were occurring frequently and the sign of the potential gradient was indeterminate.

Dr. T. W. Wormell also questioned Gunn's explanation of the separation of the charge in a thundercloud. The velocities relative to air of the precipitation particles and cloud droplets would have the same ratio in still air and in a vertical wind, and no increased separation would be expected.

Dr. F. J. Scrase spoke of the difference between thunderstorm and shower clouds. Although the magnitudes of the charges observed on rain from these clouds were similar, showers showed a considerable excess of negative charge. He suggested that shower clouds might be bipolar, without the positive region of charge in the base. Mr. R. F. Jones had observed greater signal intensities in radar echoes from thunderclouds than from shower clouds; this suggested to Dr. Scrase that bigger drops might exist in thunderstorms, with consequent greater possibility of formation of low positive charges by the breaking-drop mechanism. Dr. Scrase also commented on the inadequate sampling in Gunn's observations—in the thunderstorm he estimated that 1 drop in 10^{10} was sampled.

Mr. R. F. Jones confirmed Dr. Scrase's report of his findings, but added that in thunderstorms it was common for lightning not to be observed until more than ten minutes after the radar echo had attained its maximum intensity. He also mentioned that although it seemed possible to interpret the echo only as being from liquid water, the top of the echo-producing column was almost always at a temperature below $-40°$C.

Mr. C. R. Bruce, of the Electrical Research Association, raised the question of the magnitude of the fields observed by Gunn, which were considerably greater than those suggested by the alti-electrograph. This point was of considerable importance in the theory of propagation of the lightning discharge.

Dr. Robinson, in replying to the discussion, pointed out that 15 per cent. of the useful alti-electrograph ascents had come to a violent end in rapidly increasing fields, so the results could hardly be used as evidence of total absence of fields of the order of 1,000 v./cm. The fields shown by the alti-electrographs below the cloud, however, could not be reconciled with the assumptions made by Sir George Simpson and now by Dr. Chalmers and Dr. Wormwell in explaining the relation of the charge on rain to the field at the ground. He regretted very much that Gunn had not taken the opportunity to observe and publish the field at the ground and at several heights below the cloud base when observing the electrification of ordinary rain.

METEOROLOGICAL RESEARCH COMMITTEE

The eleventh meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on November 2, 1950. High-level photography of cloud systems as an aid in forecasting and as a possible research tool was discussed at length; many interesting photographs were displayed.

After considering a brief review of recent literature, the Sub-Committee agreed that the ideas of dynamic instability (in the restricted sense currently attributed to dynamic instability) have little or no useful application in practice.

The desirability of investigating weather conditions leading to ice on the Icelandic fishing grounds was also discussed.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on November 22, 1950, Dr. R. C. Sutcliffe, Vice-President, in the chair, the following papers were read:—

Robinson, G. D.—Notes on the measurement and estimation of atmospheric radiation—2*.

Dr. Robinson first explained in broad outline the application of the Elsasser and Kew radiation charts to the computation of the emission of infra-red radiation from a layer of the atmosphere, given the water-vapour content and temperature, and dealt more closely with the dependence of the coefficient of emissivity of water vapour on temperature. Comparison of the observed and computed radiation flux showed that the error of the computed values when plotted against screen temperature gave parallel curves for both the Elsasser and Kew radiation charts. This comparison showed that the emissivity increased with temperature for the range of both lengths and temperatures dealt with.

Dr. Robinson then turned to his measurements of the radiative heating and cooling of the lowest metre of the air over grass at night which showed that the net flux of radiation out from the top of this layer could be ten times the flux equivalent to the rate of cooling. He ascribed the difference to heating of the air by downward eddy convection which, in answer later to Sir David Brunt, he explained, included the latent heat of water vapour moving downward to condense on the grass. Finally, Dr. Robinson stated that measurement of the temperature of the ground was not so very difficult after all, as he had found that, on both cold nights and hot sunny afternoons, measurements of the surface temperature by a radiometer agreed extremely well with the readings of an ordinary grass minimum thermometer laid on the grass.

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* *Quart. J. R. met. Soc., London*, **76**, 1950, p. 37.

Mr. E. Gold and Sir David Brunt discussed the variation of emissivity with temperature which appears to be equivalent to assuming radiation to be proportional to $T^{3 \cdot 5}$ instead of T^4. Prof. P. A. Sheppard asked if Dr. Robinson had used Ångström's radiation measurements in a balloon flight for determining the emissivity at low temperatures, but, for instrumental reasons, Dr. Robinson doubted their accuracy.

*Penman, H. L.—Evaporation over the British Isles.**

Dr. Penman has given, in the last two years, a formula enabling the long-period evaporation from an extended water surface in a given area to be computed from the sunshine, temperature, humidity and wind speed over the area, and empirical factors, variable with season, for deriving values for the evaporation from vegetation. He described at the meeting a comparison between the computed value of evaporation from open water with the measured evaporation from a reservoir near Colchester, and a comparison between the computed evaporation from vegetation and the difference between rainfall and run-off over Great Britain. Over periods sufficiently long for the changes in underground water storage to be neglected the evaporation and run-off should balance rainfall. Striking agreement was found in both tests. The map of evaporation showed that over the south-east and south coast of England and south-west Ireland it is 20 in. per annum, and over Scotland, north England and eastern Ireland it is 15 in. The intermediate, 17·5 in., line runs from London to Liverpool.

In the discussion, Mr. Gold described researches into the relation between run-off in a given three-month period to the rainfall in the same and earlier periods. Dr. Glasspoole showed that over the Thames valley the rainfall and run-off varied fairly closely together in time but the difference between them was markedly different. Mr. McClean, speaking as an engineer, doubted the accuracy of evaporation computed from rainfall and run-off because he considered only the run-off was accurately measurable. Dr. Penman, speaking again, dealt with underground water storage and showed that a well record, representative of the storage, agreed very closely over a long period of years with the quantity: rainfall minus run-off and minus computed evaporation from vegetation.

LETTERS TO THE EDITOR

Cloud cap over Sandray, Outer Hebrides

On a recent short stay at Castlebay, Isle of Barra, Outer Hebrides, I was informed by several inhabitants that a well defined cloud over the Isle of Sandray was a sure sign of a spell of rain in Barra.

This well defined cloud appeared on two occasions during my stay on the island, and within about half an hour of its appearance rain set in, accompanied by high wind; and on each occasion the rain continued unabated for at least

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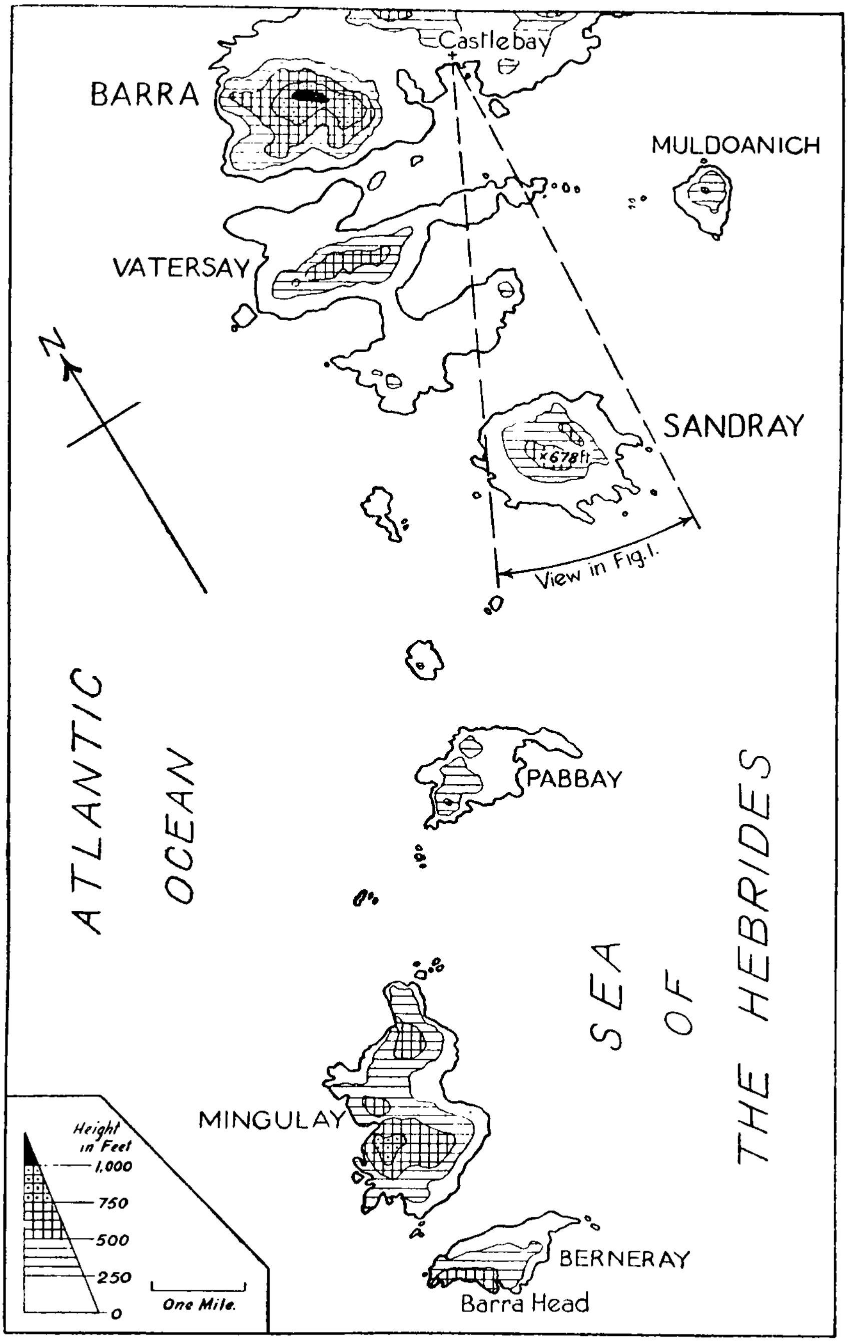
Quart. J. R. met. Soc., London,* **76, 1950, p. 372.



Castlebay
BARRA
MULDOANICH
VATERSAY
N
SANDRAY
x678ft
View in Fig. 1.
ATLANTIC
OCEAN
PABBAY
SEA
OF
THE HEBRIDES
MINGULAY
Height in Feet
1,000
750
500
250
0
One Mile.
BERNERAY
Barra Head

FIG. 2—SOUTHERN ISLANDS OF THE OUTER HEBRIDES

twelve hours. It is of interest to note that apart from very brief breaks of a few minutes' duration, the sky was totally overcast with a sheet of stratocumuliform cloud during the whole seven days of my visit. The base of this cloud sheet was generally at about 1,000 ft. but at times came down in ragged patches to about 400 ft.

The "rain-warning" cloud over Sandray would form, in sharp lenticular outline, beneath the stratocumulus sheet and, by the time the rain belt reached Castlebay, the well defined outline would become diffuse and appeared to merge with the general cloud sheet above it.

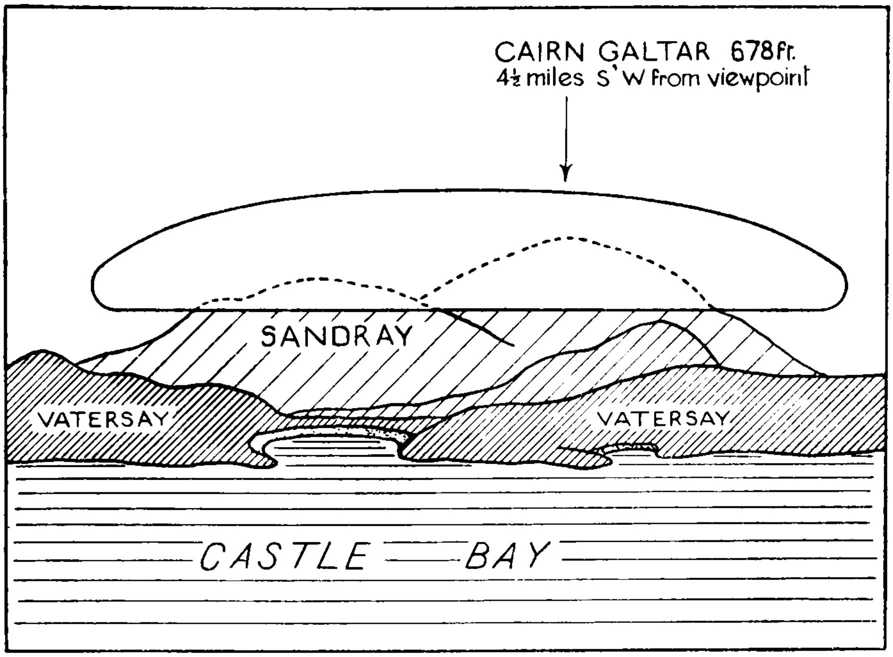


FIG. 1—CLOUD CAP OVER SANDRAY

I took particular note of the surface wind at the time, and the lenticular cloud cap formed when the wind was from the S. or SE. Fig. 1 shows the appearance of the cloud cap at 2010 G.M.T., June 25, 1950, and Fig. 2 shows a map of the area. It will be noted that the Isle of Sandray is fully exposed to southerly winds, the nearest landfall to the south being the north coast of Ireland, some 100 miles or more away.

It is of interest to note that cloud caps appearing over the adjacent islands of Muldoanich, Pabbay and Mingulay do not appear to take sharp lenticular outlines as those forming on Sandray itself; and if other less defined caps do form on Sandray, they do not seem to indicate the arrival of prolonged rainy periods in Barra, although brief showers may be experienced.

D. L. CHAMPION

56 Forestdale, Southgate, London, N.14, July 10, 1950

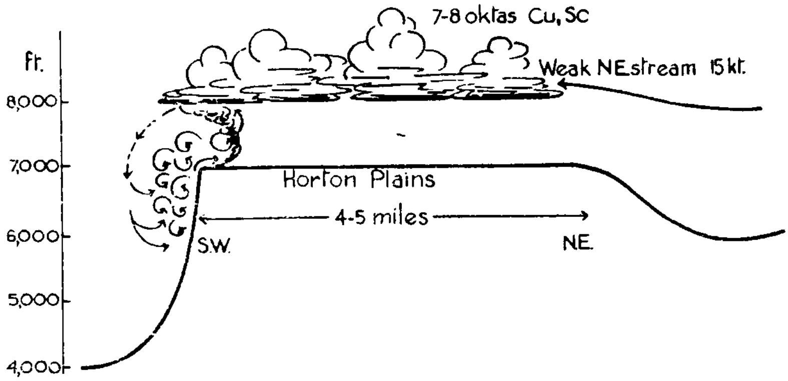
Lee eddies and cloud formation

The visible demonstration of the vertical eddies that exist to the leeward of an obstacle in a wind stream must be comparatively rare in nature. Such a demonstration, however, was afforded the writer when visiting Horton Plains, Ceylon.

Horton Plains is a plateau, 7,000 ft. high, in the central hill district of Ceylon. The main mountain range runs roughly north-south in this area, flattening out for some four or five miles to form the plains, which are approximately four miles wide from east to west. On the north-east side, a steep, but not precipitous, jungle-covered slope falls away for 1,000 ft. to an upland basin. To the south-west the plain is bounded by a precipice which falls sheer for 1,000 ft. and then only just less steeply for a further 2,000 ft.

On the evening (1700 I.S.T.) of March 20, 1950, a weak NE. monsoon air stream covered Ceylon; 7–8 oktas light cumulus and stratocumulus cloud were about 1,000 ft. above Horton Plains and were being carried south-south-west at an estimated speed of 15 kt. On the plateau, and at a distance of rather less than half a mile from its south-west edge, the surface wind was negligible, but puffs of thick fog could be seen rolling up over the edge of the precipice and advancing one or two hundreds of yards north-eastwards over the plateau before being swept upwards towards the main cloud base and then carried south-westwards again.

The viewpoint on the plateau in relation to the general wind stream and the topography of the precipice, was such that a partly "sectional" view of the leading edge of the fog was obtained and its convex curvature could be clearly seen, indicating the eddy formation. The roll or leading edge of fog was alternately very definite and either stationary or advancing north-eastwards, or very ragged and undefined and retreating towards the cliff edge. These alternations were not timed accurately, but were of the order of a few minutes and were probably due to the formation of an eddy and its subsequent detachment down wind.



SKETCH DRAWN IN THE METEOROLOGICAL OFFICE FROM THE DESCRIPTION BY W. D. S. MCCAFFERY.

The formation of the cloud which made these eddies visible can be explained by assuming that eddies forming in the air spilling off the plateau, drew up warmer and moister air from the plains beneath, the uplift being sufficient to cause condensation.

The thick fog which shrouded the edge of the precipice was in striking contrast to the more usual phenomenon of "cloud clearing to leeward of high ground".

W. D. S. MC CAFFERY

Negombo, Ceylon, July 14, 1950

Corrosion in a Dines anemograph head

Users of the Dines anemograph may perhaps be interested to learn of a possible cause of damage to the head of this instrument.

A new anemograph was installed at the Royal Observatory, Hongkong, in 1939. The cylindrical shield which covers the pressure and suction outlets at the base of the head was stuffed with cotton waste, to prevent it from vibrating and possibly fracturing in typhoon winds. When the Observatory was re-occupied after the Japanese occupation, the velocity recorder was found to be sluggish and lacking in sensitivity. The trouble was traced to the pressure and suction tubes, which were corroded right through within the lower part of the shield, where they were in contact with the cotton waste. Corrosion had also attacked the mast itself at this level, but fortunately the damage was discovered before the head became completely detached.

The lower part of the waste was found to be damp when it was removed; it must have accumulated hygroscopic particles from smoke or from salt-water spray (the sea front is only a quarter of a mile away). The brass shield, the damp waste and the iron tubes evidently formed an electrolytic cell, with the result that the iron was slowly dissolved.

G. S. P. HEYWOOD

Royal Observatory, Hongkong, September 20, 1950

NOTES AND NEWS

Market Produce Show, Southampton—June 30–July 1, 1950

At the request of the National Farmers' Union, the Meteorological Office (Agricultural Meteorology Branch) provided an exhibit at the Market Produce Show, held on the Common, Southampton, on June 30 and July 1. After experience at the similar show in 1949, the chosen items were mostly confined to the few necessary to give emphasis to the main interests of producers in present-day weather. These interests are the need for irrigation of vegetable, salad and soft-fruit crops during the summer, and the economics of growing them under cloches.

The Meteorological Office tent was well placed next to that of the Ministry of Agriculture, and the exhibit attracted the attention of growers as well as agricultural students and many parties of schoolchildren. In a small enclosure outside the tent were displayed a large thermometer screen with the usual four thermometers, thermograph and hygrograph; a cup anemometer; a sunshine recorder; and a working experiment showed the effect on air and soil temperatures of modern cloches, a distant-reading thermograph being used to show the air-temperature contrasts. The weather was warm and sunny, and the outside exhibit attracted much attention in consequence. Inside the tent the main feature of the display consisted of five vertical panels reaching from floor to roof. Two panels showed the activities of the Office in relation to agriculture, including those of the Agricultural Meteorology Branch in particular and also the forecast and climatological facilities available to the farming community. A third panel illustrated by means of enlarged photographs the weather indications which farmers might deduce from a study of the sky. The remaining panels concentrated attention upon the variability of British rainfall and the need for irrigation, and the results of experiments on the effect of glass protection on soil and air temperatures. It was noted by many visitors that these results agreed very well with the working experiment demonstrated in the enclosure. On tables round the walls of the tent were shown various meteorological instruments of particular interest to agriculturists, and appropriate literature was there to be read. The meteorological office at Eastleigh co-operated by sending daily forecasts and weather reports. The blackboard prominently displaying "Forecast—fair and warm" without any "perhaps" or "here and there" was a special comfort to the organizers, whilst several chairs provided a much needed rest to visitors and were not the least appreciated part of the show.

In addition to the Meteorological Office's own display there were included in that of the Ministry of Agriculture, next door, two models which had a bearing on their subject, which was the proper establishment of an apple orchard. One contribution consisted of a topographical and geological model indicating the importance of exposure and soil as regards frost incidence in an orchard, and the other of a wind tunnel illustrating the protection from wind afforded to orchard trees by a low hedge. Material was also provided for a special exhibit designed to demonstrate the effect on the date of flowering of cooling bulbs in store before planting.

Next year the Market Produce Show is to be held in London in connexion with the Festival of Britain, so that a more ambitious effort may be called for, but that the simplicity of this display at Southampton was appreciated was plainly shown by the encomiums of our many visitors.

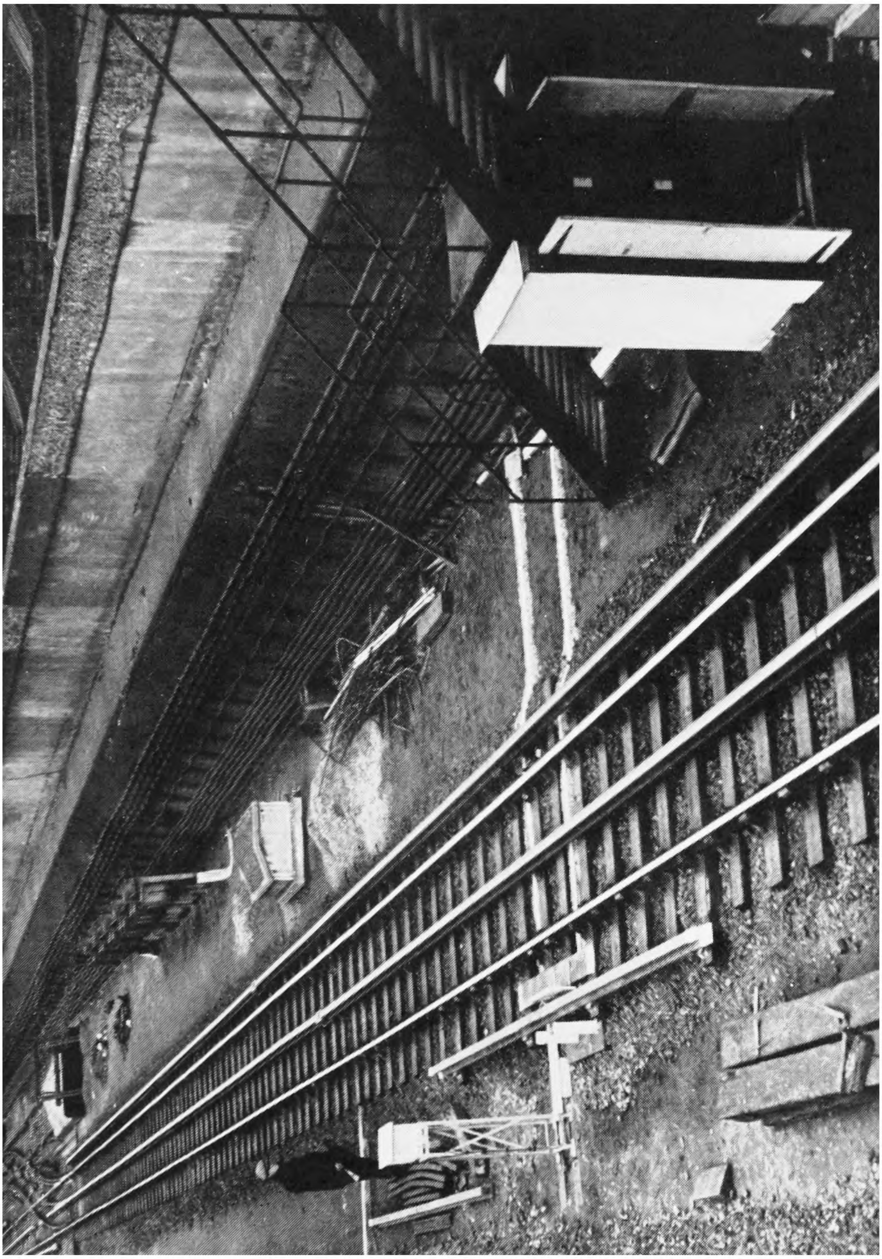
Ice formation on conductor rails

Daily forecasts of the prospects of ice formation on electrical conductor rails are issued during winter months by the Central Forecast Office, Dunstable, to the Southern Region of British Railways and to the London electrified railways. When icing is forecast arrangements are usually made by the railway authorities either to run special de-icing trains or, in the case of London Transport, to switch in the de-icing baths which are installed throughout the open sections of the track.

The ice deposits which effectively insulate the rails and interfere with the running of trains are those which are adhesive in character and are not brushed off by the collecting "shoes" of passing trains. Examples are: a deposit of dew which subsequently freezes, and rain, or wet snow, falling on conductor rails that are at subfreezing temperatures. Hence, to forecast the icing risk it is usually necessary to estimate the temperature to which the conductor rail will fall during the period covered by the forecast. This temperature naturally varies with the exposure of the rail, particularly on a radiation night, and, other factors being equal, may be very different where the line runs through a cutting from what it is on an embankment or on open level ground. The meteorologist's knowledge and experience of grass minimum temperatures and their relationship to air temperatures at 4 ft. above ground, materially assist him in forecasting grass temperatures, but little is known of the relationship between the temperature of an electrically insulated metal rail and that of the surrounding air, either at ground level or a few feet above.

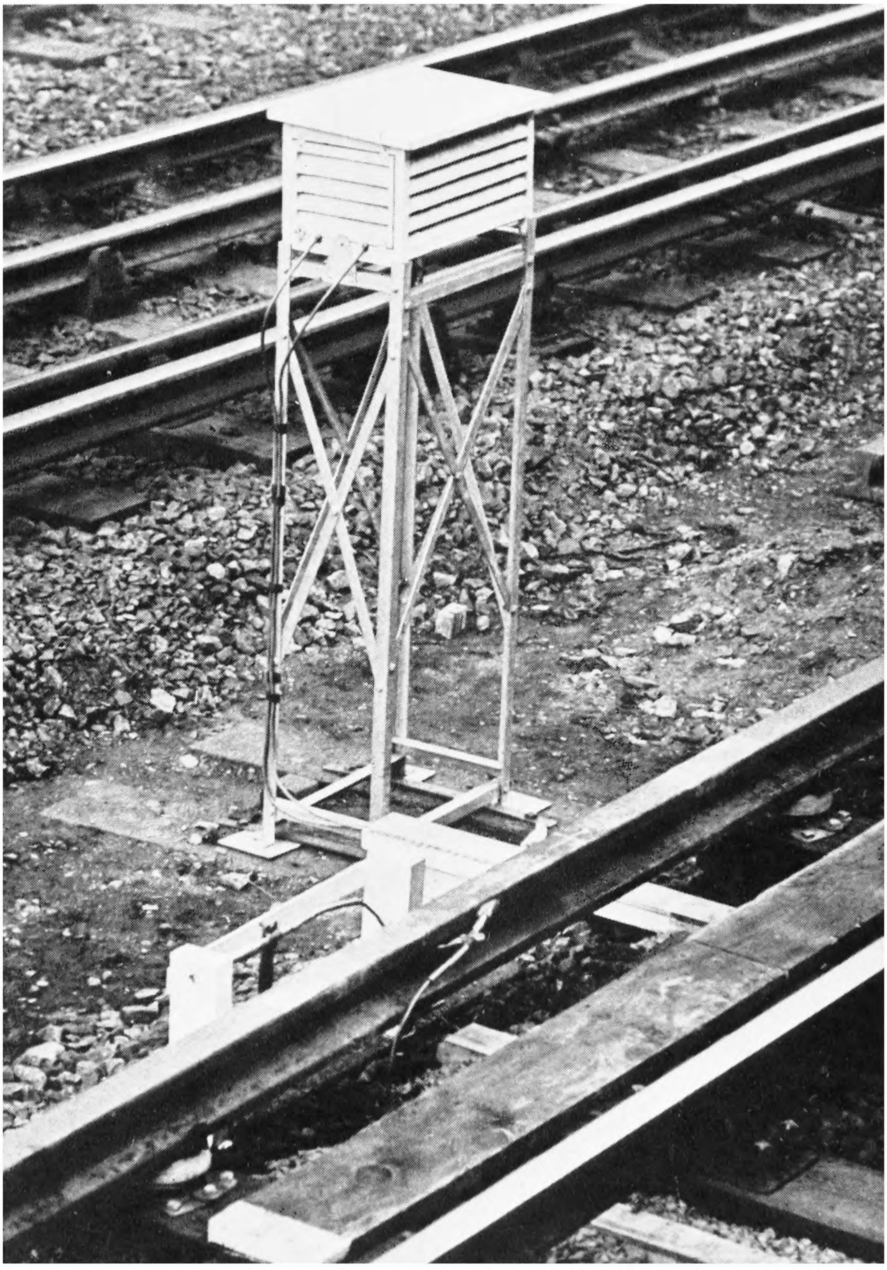
To obtain some information about this the Meteorological Office is collaborating with the London Transport Executive in the installation of a thermometric system to record rail temperatures, and the temperature and humidity of the ambient air. The site of the installation is just outside Barons Court station on the District and Piccadilly Lines, where a 30 ft. length of "dummy" conductor rail has been mounted alongside the running rail (see photograph opposite). This has been drilled diagonally at its mid-point

[*To face p.* 24



SITE OF THERMOMETRIC SYSTEM NEAR BARONS COURT STATION.

To face p. 25]



SCREEN HOUSING DISTANT-READING THERMOMETER BULBS and into the drilling has been inserted the bulb of a Negretti & Zambra mercury-in-steel distant-recording thermometer, the bulb being in thermal contact with the head of the rail. A second such thermometer is mounted alongside the rail at the same height above the ground (see photograph opposite) to record the air temperature at that level for comparison with that of the rail. In addition, dry- and wet-bulb distant-recording thermometers are installed at the standard height of 4 ft. in a screen which has been erected alongside the length of dummy rail. The recorders for these two pairs of thermometers are housed in a small cabin specially constructed on the opposite side of the track (seen in the photograph facing p. 24 with the doors open).

Daily inspection and maintenance of the recorders is carried out by the technical staff of London Transport, who also make observations of the character and adhesion of ice forming on the surface of the dummy rail. These observations, together with the thermometric records, are to be sent to the Central Forecast Office, Dunstable, for the study of the relationship between air and rail temperatures at the same level, and between these and air temperatures at 4 ft. The association of ice formation on the rail with the humidity as recorded at 4 ft. will also be examined.

At a later stage similar installations may be set up at two or three other locations, having different types of exposure.

Temperature at 200 mb. in relation to the pressure at the tropopause

A study of the frequencies of different temperatures at different pressure levels, undertaken in the upper air climatological section of the Meteorological Office in the course of the preparation of charts of standard deviation of upper air temperature over the world, brought to light the fact that at 200 mb. over the British Isles the distribution is not normal in the statistical sense but shows two maxima. This abnormality is most conspicous in winter, and it was suggested that it might be due to the fact that the 200-mb. surface lies sometimes in the stratosphere and sometimes in the troposphere and that occasions of low tropopause are more frequent in winter than in summer.

The temperature frequencies at Larkhill were therefore re-tabulated and classified into five groups according to the tropopause pressure, namely, very high tropopause with pressure below 200 mb., three groups of intermediate tropopauses with pressure 200–249, 250–299, 300–349 mb., and very low tropopauses with pressure of 350 mb. and over. The results for the mid-season months January, April, July and October are shown in Table I and in Fig. 1. In the figure the percentage frequencies for steps of 2 degrees Fahrenheit are represented; and, in order to simplify the diagram, all occasions of tropopause pressure of 250 mb. and over are grouped together. In the table (which gives actual values not percentages) the five pressure groups are shown separately, but to reduce the size of the table the temperature is in four-degree ranges.

The average pressure at the tropopause in January for the period studied is 239 mb. The percentage frequencies of temperature for values of the tropopause pressure above and below this average are shown in Fig. 2.

The association of low temperature with high tropopause (low tropopause pressure) and *vice versa* is very clearly shown.

TABLE I—FREQUENCY OF TEMPERATURE AT 200 MB. IN RELATION TO TROPOPAUSE PRESSURE

Larkhill (all hours) Period—July 1945–July 1949

Temperature (Fahrenheit) at 200 mb.

Tropopause pressure	−95° to −92°	−91° to −88°	−87° to −84°	−83° to −80°	−79° to −76°	−75° to −72°	−71° to −68°	−67° to −64°	−63° to −60°	−59° to −56°	−55° to −52°	−51° to −48°	−47° to −44	−43 to −40°	over −40°	Total
mb.	*number of occasions*															
JANUARY																
<200	3	11	41	27	12	4	1	1	...	...	...	...	...	...	...	100
200–249	1	6	29	38	38	29	25	14	10	7	3	...	...	...	...	200
250–299	...	...	...	2	2	6	11	13	24	25	13	4	...	...	...	100
300–349	...	...	...	...	...	1	1	1	5	17	9	7	1	...	...	42
⩾350	...	...	...	...	...	...	...	...	3	7	4	5	2	...	...	21
Total	4	17	70	67	52	40	38	29	42	56	29	16	3	...	...	463
APRIL																
<200	...	...	10	26	37	18	2	1	...	...	...	...	...	...	...	94
200–249	...	3	11	26	38	42	34	25	15	13	2	3	...	...	...	212
250–299	...	...	...	2	1	2	9	9	7	19	22	4	1	1	...	77
300–349	...	...	...	...	...	...	...	...	...	4	7	5	6	2	...	24
⩾350	...	...	...	...	...	...	...	...	2	2	4	1	5	6	2	22
Total	...	3	21	54	76	62	45	35	24	38	35	13	12	9	2	429
JULY																
<200	...	...	...	1	6	24	40	25	19	6	1	...	...	...	...	122
200–249	...	...	...	1	5	28	57	72	58	59	30	15	3	...	...	328
250–299	...	...	...	...	...	...	...	2	2	12	14	37	20	9	2	98
300–349	...	...	...	...	...	...	...	...	...	...	1	6	5	7	1	20
⩾350	...	...	...	...	...	...	...	...	...	...	1	...	1	2	...	4
Total	...	...	...	2	11	52	97	99	79	77	47	58	29	18	3	572
OCTOBER																
<200	...	1	8	30	52	46	29	7	4	...	1	...	...	...	...	178
200–249	...	...	2	14	28	39	52	31	14	5	2	1	...	...	...	188
250–299	...	...	...	...	...	1	8	24	25	11	5	1	...	...	...	75
300–349	...	...	...	...	...	...	...	4	6	3	5	3	...	...	...	21
⩾350	...	...	...	...	...	...	...	...	1	2	1	3	1	1	...	9
Total	...	1	10	44	80	86	89	66	50	21	14	8	1	1	...	471

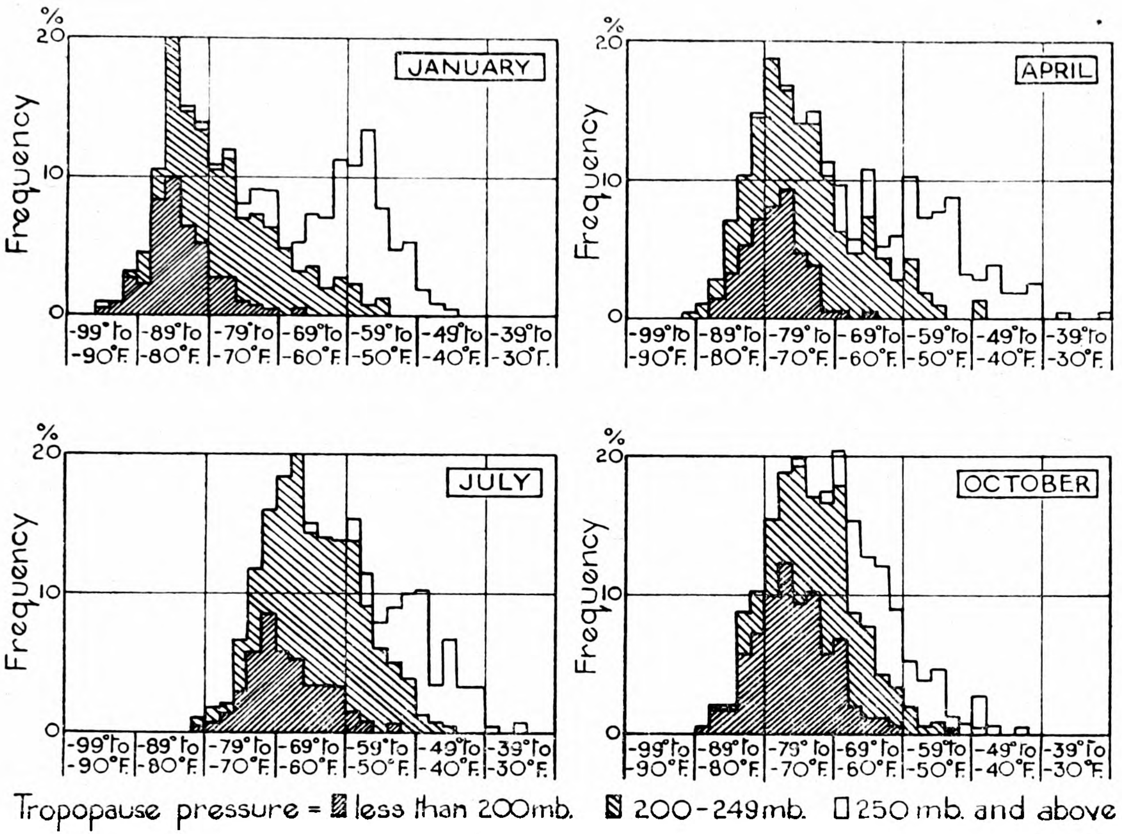


FIG. I—PERCENTAGE FREQUENCY AT LARKHILL OF 2-DEGREE STEPS OF TEMPERATURE AT 200 MB. IN RELATION TO PRESSURE AT THE TROPOPAUSE

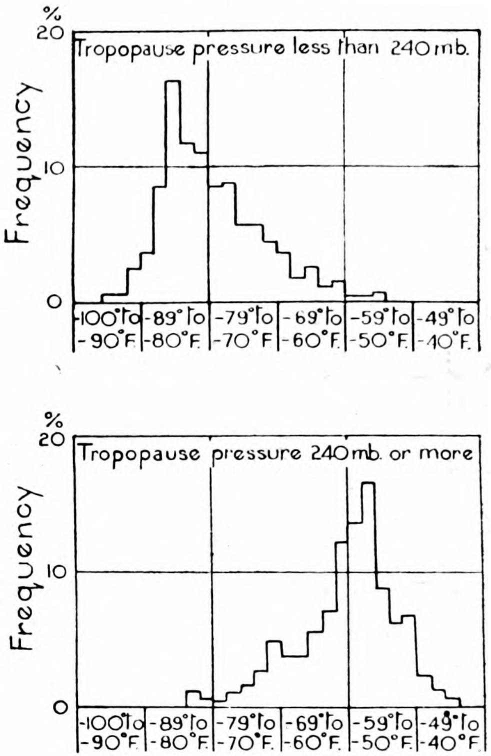


FIG. 2—TEMPERATURE FREQUENCIES AT 200 MB. IN JANUARY AT LARKHILL

METEOROLOGICAL OFFICE NEWS

Mr. Ralph Sydney Read, I.S.O., M.A., B.Sc., A.R.C.S., F.Inst.P.—Mr. Read, Principal Scientific Officer, retired on December 4, 1950, after almost 31 years' service in the Meteorological Office. After student days at the Royal College of Science, London, and Sidney Sussex College, Cambridge, a lectureship at University College, Exeter, Government work and service with the Meteorological Section, R.E., 1914–18, Read came to the Office as a Senior Professional Assistant in January 1920. He was destined to be closely and prominently associated with meteorological services for aviation for the whole of his Office career. An initial three-and-half years at Lympne airport in the early days of scheduled air services to the Continent was followed by thirteen years at headquarters as deputy to the Head of the Branch responsible for meteorological services for aviation. During this period he was concerned with actual forecasting and also with administrative and organizational duties, at times concurrently. He was one of the first to appreciate the importance of the "frontal" ideas of the Norwegian school of meteorologists and to apply them. In those early years of the growth of aviation, when official and private long-distance flights and flying displays at Hendon made headline news, Read played a leading and often arduous part as meteorologist for the new enterprises.

For about three years before the second world war he was in charge at Croydon airport, then in its heyday as chief centre of civil aviation services in the United Kingdom. This close association with civil aviation was continued in the early months of this war in his capacity as Liaison Officer with the Headquarters of the Director-General of Civil Aviation, Bristol. From June 1940 until February 1944 he was Senior Meteorological Officer at H.Q. No. 11 Group, one of the most responsible posts with the R.A.F. in those war years. Thereafter, as Head of Branch at Headquarters, he was intimately engaged, at first with the requirements of the Army and R.A.F. prior to and during the war operations in north-west Europe, and subsequently with the modified but, in the circumstances, perhaps no less exigent needs of the post-war R.A.F. at home.

Mr. Read's service to meteorology in all its different aspects was marked by ability coupled with keenness and a certain East Anglian fixity of purpose. His great experience was always fully at the disposal of colleagues of all grades. He was well known to hundreds of people actively concerned with flying, from practising pilots and navigators to more eminent and senior personalities.

But his colleagues remember also Read's other less official attributes; his friendliness and individual sense of humour, his enjoyment in social occasions, his fondness for horticulture, his walking expeditions. His active participation in athletic activities for the Office and Air Ministry—running, rugger, soccer and cricket—continued into his late forties when most of his contemporaries were spectators, or arm-chair critics. His close interest in sport remains, though the early morning swim in the Thames near his home was abandoned comparatively recently. For some years he represented the Office staff on the Council of the Institution of Professional Civil Servants.

At a well attended ceremony on December 4, 1950, the Director, Sir Nelson Johnson, referred to Mr. Read's valued services and qualities, and, in conveying the earnest good wishes of the staff to Mr. Read, asked him to accept a miniature greenhouse, exquisitely fashioned by Mr. A. J. Tabor, in token of the large-scale article for which the staff had subscribed. Mr. Read, in some thoughtful farewell remarks, touched on incidents selected from his experience, contrasted past with present meteorological facilities, and paid tribute to the team spirit within the Meteorological Office and emphasized the importance of sustaining it within such a far-flung organization. Mr. Read's numerous colleagues and the many other friends who were unable to be present on the 4th will wish him every happiness in his years of freedom from official responsibilities.

Awards for long service as voluntary meteorological observers at sea.—Three master mariners who have made consistently good voluntary observations at sea for the Meteorological Office over a period of more than 15 years have recently had presentations made to them by the Director. The awards have taken the form of barographs with an inscription on a silver plate which reads "Presented by the Director of the Meteorological Office to . . . . in recognition of his valuable meteorological work at sea, 19... to 19...".

The presentation to Captain G. Kinnell, O.B.E., of the New Zealand Shipping Co. was made aboard his ship, the *Rangitata*, in Victoria Dock, London, on November 29, by Sir Nelson Johnson. Mr. H. Whitehouse, Chairman of the Company was host at a very pleasant luncheon party to mark the occasion, at which the guests included representatives of the Honourable Company of Master Mariners.

On December 13, in the Captains' Room at Lloyds, at the weekly luncheon of the Honourable Company of Master Mariners, Sir Nelson Johnson made the presentations to Captain J. A. Myles of the Cunard Line and to Captain R. A. Penston of Messrs. T. & J. Brocklebank, Ltd. Captain Myles has been a voluntary observer since 1921 and Captain Penston since 1926. The guests at the luncheon included Sir Stanley Aubrey, Deputy Chairman of Lloyds.

Rosters in Malaya.—Malaya is a meeting place of nationalities and one of the problems facing the Meteorological Office in that country is the making of assistant rosters which will take into account all the public, national and religious holidays which the members of the different nationalities can claim. A roster may be composed of a selection of Chinese, Hindu, Muslim, Jew, Buddhist or Sikh staff whose national and religious festivals are all different and do not occur on fixed days. They may be determined either by a particular astronomical sign or by a calendar different from our own, one being a variable calendar containing twelve or thirteen months. Makers of rosters at home will be able to appreciate some of the difficulties to be overcome.

Television.—A television programme, "London Town", broadcast on November 10, 1950, included scenes of a visit by Mr. Richard Dimbleby to the roof of the Meteorological Office, Kingsway. The exposure and instruments were shown, and some autographic records and diagrams connected with the daily work of the general inquiry section of the Office were televised "live" during an interview at the Alexandra Palace studios.

Sports activities.—The Office has been very successful in the recent Air Ministry championships:—

Swimming.—Miss B. J. Davies won the ladies' championship.

The Office won the team race for the second year running and gained the first three places in the free-style and breast-stroke races and the first two in the back-stroke.

Mr. A. F. Lewis has won the free-style and the back-stroke races for the last three years and Mr. T. D. Abbott the breast-stroke race for the second year running. Mr. Abbott was third in the Civil Service breast-stroke championship, Mr. A. R. Hosker third in the Civil Service plunging championship and Mr. A. F. Lewis (now in the Falkland Islands) and Mr. S. W. Lewis were fourth and fifth respectively in the Civil Service mile swimming championship.

Cross-country Championship.—The Office won the team event and second and third places (Messrs. G. F. Burton and G. M. Band) in the individual event held at Woodford on December 9. The race was originally run at Hayes on November 25 when Mr. W. Lawson came in first in both the individual race and the sealed handicap, with Mr. G. M. Band second, and Mr. D. Marriott third. Owing to fog, however, one competitor lost his way and the race was declared void. Mr. Lawson was subsequently injured and unable to take part when the race was run for the second time.

The Office has gained 43 points in the Bishop Shield competition which restarted in September.

Annual Soirée.—The 1951 Soirée has been arranged for Monday, March 5, and, as in recent years, it will be held at the Victoria Halls, Bloomsbury. Last year, the gathering was truly representative, outstations accounting for nearly half of those present. Once again it is hoped that a large number of staff with their wives and friends will come and ensure a successful evening.

WEATHER OF NOVEMBER 1950

Mean pressure was above 1015 mb. over southern Europe and the Mediterranean, and over most of North America and the Atlantic between the east coast of the United States and north-west Africa. It was above 1025 mb. over part of Alaska. There was an area with mean pressure between 1000 mb. and 1005 mb. which included Iceland, Scotland, the Faeroes and the south-west coast of Norway.

Mean pressure was about 15 mb. above the November normal in central and southern Alaska, and nearly 10 mb. above the normal southward of Greenland, but was about 5 mb. below normal over most of central Europe, the British Isles, and the Azores.

In the British Isles the weather was very wet over most of England and Wales and south-east Scotland, but drier than usual on the whole in west and central Scotland and Northern Ireland. In England and Wales it was the wettest month of the year.

On the 1st a trough of low pressure extending from the Hebrides to south-east Ireland moved east, while a small secondary disturbance over Brittany moved north-east; rain fell generally and was moderately heavy in the north-west. On the 2nd a secondary depression developed off west Ireland and moved east-south-east; moderately heavy rain occurred in the south and east on the 2nd and there were scattered showers on the 3rd. From the 3rd to the 6th an anticyclone to the north of Scotland and an associated ridge extending southward to the west of Ireland moved slowly east and was associated with a spell of mainly fair weather apart from scattered showers, chiefly in eastern districts; in the west there were long sunny periods. On the 7th and 8th an intense depression south-east of Greenland moved a little south-east and a trough of low pressure moved east-south-east across the British Isles; rain occurred in most parts, but the 7th was a sunny day in the south. On the 10th a small depression moved north-east from the Bay of Biscay causing heavy rain locally in south and east England. Thereafter, on the 11th a trough west of Ireland moved east and was followed on the 12th by another trough moving south-east. Rain fell generally and was heavy locally. In the rear of these disturbances a cold north-westerly air stream covered the British Isles and showery weather, with sunny periods, prevailed. On the 15th and 16th a small depression south-west of Ireland moved quickly east across southern England giving rain in this area, and on the 16th a shallow depression drifted south-east over Scotland.

A very unsettled spell ensued with heavy rain, except in the north-west. On the 18th a deep depression approached north-west Ireland and subsequently moved south-east to Wales and then turned north-east; this was followed on the 20th by another disturbance which moved east along the English Channel and later turned north to the southern North Sea and gradually filled. Widespread heavy rain occurred in southern districts of England and Wales on the 20th, in south-east Scotland on the 21st and in north-east England on the 22nd (2·35 in. at Kingside, Lammermuir Hills, on the 21st and 2·09 in. at Weardale Water Works, Durham, on the 22nd). Local gales occurred at times at exposed places between the 18th and the 23rd and thunder was recorded locally from the 18th to the 21st.

Subsequently a ridge of high pressure associated with an anticyclone south of Greenland moved south over the British Isles and cold mainly fair weather, apart from fog, prevailed until the 27th. On that day a complex Atlantic depression approached our south-west coasts; on the 28th one centre moved rapidly across southern Scotland and on the 28th and 29th a second centre moved from south-west Ireland across northern England. Heavy rain occurred in the south-west districts of England and Wales on the 27th (2·68 in. at Princetown and 2·35 in. at Brechfa, Carmarthen) and moderate rain fell generally on the 28th. On the 29th and 30th a trough moved south-east across the country giving further rain (2·30 in. at Kinlochquoich, Inverness-shire, on the 29th).

Among low screen minimum temperatures may be mentioned 14°F. at Braemar on the 17th, 18°F. at Peebles and Eskdalemuir, and 21°F. at Northolt and Silloth on the 26th, and 20°F. at Ballykelly, Garvagh and Armagh on the 27th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	60	20	−0·4	180	+4	95
Scotland	57	14	−1·7	118	0	117
Northern Ireland ...	55	20	−2·2	79	−1	122

RAINFALL OF NOVEMBER 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	4·74	201	*Glam.*	Cardiff, Penylan ...	6·52	161
Kent	Folkestone, Cherry Gdn.	7·86	242	*Pemb.*	Tenby	6·62	153
,,	Edenbridge, Falconhurst	7·20	203	*Card.*	Aberystwyth	5·41	146
Sussex	Compton, Compton Ho.	7·79	204	*Radnor*	Tyrmynydd	8·80	132
,,	Worthing, Beach Ho. Pk.	5·74	179	*Mont.*	Lake Vyrnwy	6·94	121
Hants.	Ventnor, Roy. Nat. Hos.	5·66	176	*Mer.*	Blaenau Festiniog ...	11·14	105
,,	Bournemouth	6·03	177	*Carn.*	Llandudno	3·85	133
,,	Sherborne St. John ...	5·40	189	*Angl.*	Llanerchymedd ...	4·69	111
Herts.	Royston, Therfield Rec.	4·64	199	*I. Man*	Douglas, Borough Cem.	4·78	101
Bucks.	Slough, Upton	4·87	219	*Wigtown*	Port William, Monreith	3·06	71
Oxford	Oxford, Radcliffe ...	4·42	192	*Dumf.*	Dumfries, Crichton R.I.	2·90	79
N'hants.	Wellingboro' Swanspool	3·80	177	,,	Eskdalemuir Obsy. ...	4·84	83
Essex	Shoeburyness	3·78	177	*Roxb.*	Kelso, Floors	4·54	197
,,	Dovercourt	3·90	181	*Peebles*	Stobo Castle	3·82	115
Suffolk	Lowestoft Sec. School ...	3·61	154	*Berwick*	Marchmont House ...	6·05	202
,,	Bury St. Ed., Westley H.	4·36	190	*E. Loth.*	North Berwick Res. ...	3·49	156
Norfolk	Sandringham Ho. Gdns.	4·47	180	*Midl'n.*	Edinburgh, Blackf'd. H.	3·37	150
Wilts.	Bishops Cannings ...	5·87	205	*Lanark*	Hamilton W. W., T'nhill	2·82	79
Dorset	Creech Grange... ...	6·80	165	*Ayr*	Colmonell, Knockdolian	4·39	88
,,	Beaminster, East St. ...	6·94	175	,,	Glen Afton, Ayr San. ...	5·24	95
Devon	Teignmouth, Den Gdns.	5·75	180	*Bute*	Rothesay, Ardencraig ...	5·42	107
,,	Cullompton	7·60	221	*Argyll*	Morvern (Drimnin) ...	6·39	94
,,	Ilfracombe	7·21	183	,,	Poltalloch	4·85	86
,,	Okehampton Uplands	11·00	207	,,	Inveraray Castle ...	6·37	75
Cornwall	Bude, School House ...	7·70	216	,,	Islay, Eallabus	4·01	75
,,	Penzance, Morrab Gdns.	8·40	183	,,	Tiree	4·68	97
,,	St. Austell	9·82	199	*Kinross*	Loch Leven Sluice ...	4·43	123
,,	Scilly, Tresco Abbey ...	5·63	163	*Fife*	Leuchars Airfield ...	3·35	146
Glos.	Cirencester	6·00	201	*Perth*	Loch Dhu	5·64	65
Salop.	Church Stretton ...	5·03	162	,,	Crieff, Strathearn Hyd.	2·35	54
,,	Shrewsbury	3·38	150	,,	Pitlochry, Fincastle ...	2·82	76
Worcs.	Malvern, Free Library	4·30	171	*Angus*	Montrose, Sunnyside ...	3·15	119
Warwick	Birmingham, Edgbaston	4·57	192	*Aberd.*	Braemar	3·51	91
Leics.	Thornton Reservoir ...	3·62	160	,,	Dyce, Craibstone ...	3·96	121
Lincs.	Boston, Skirbeck ...	4·03	201	,,	Fyvie Castle	5·13	148
,,	Skegness, Marine Gdns.	4·26	197	*Moray*	Gordon Castle	3·47	120
Notts.	Mansfield, Carr Bank ...	4·35	179	*Nairn*	Nairn, Achareidh ...	3·23	144
Derby	Buxton, Terrace Slopes	6·77	145	*Inverness*	Loch Ness, Garthbeg ...	5·50	132
Ches.	Bidston Observatory ...	4·41	176	,,	Glenquoich	8·73	72
Lancs.	Manchester, Whit. Park	4·44	168	,,	Fort William, Teviot ...	6·29	77
,,	Stonyhurst College ...	7·29	162	,,	Skye, Duntuilm ...	6·63	111
,,	Squires Gate	3·55	108	*R. & C.*	Tain, Tarlogie House ...	3·21	108
Yorks.	Wakefield, Clarence Pk.	4·10	193	,,	Inverbroom, Glackour...	5·15	83
,,	Hull, Pearson Park ...	4·76	217	,,	Applecross Gardens ...	5·80	90
,,	Felixkirk, Mt. St. John...	4·52	184	,,	Achnashellach	6·18	72
,,	York Museum	3·33	159	,,	Stornoway Airfield ...	4·27	77
,,	Scarborough	4·13	167	*Suth.*	Loch More, Achfary ...	7·87	92
,,	Middlesbrough... ...	5·47	258	*Caith.*	Wick Airfield	4·11	131
,,	Baldersdale, Hury Res.	5·30	143	*Shetland*	Lerwick Observatory ...	4·98	117
Norl'd.	Newcastle, Leazes Pk....	4·77	203	*Ferm.*	Crom Castle	2·59	74
,,	Bellingham, High Green	4·40	128	*Armagh*	Armagh Observatory ...	2·63	93
,,	Lilburn Tower Gdns. ...	4·70	140	*Down*	Seaforde	2·92	77
Cumb.	Geltsdale	4·64	141	*Antrim*	Aldergrove Airfield ...	2·31	71
,,	Keswick, High Hill ...	6·77	120	,,	Ballymena, Harryville...	2·83	70
,,	Ravenglass, The Grove	4·34	97	*L'derry*	Garvagh, Moneydig ...	2·86	73
Mon.	Abergavenny, Larchfield	5·68	149	,,	Londonderry, Creggan	3·37	82
Glam.	Ystalyfera, Wern House	8·83	134	*Tyrone*	Omagh, Edenfel ...	3·54	94

Frontispiece]

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MR. C. J. P. CAVE, M.A., J.P.

M.O. 548 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 80, No. 944, FEBRUARY 1951

Mr. C. J. P. CAVE, M.A., J.P.

Captain Cave, as he came to be respectfully and affectionately known by the officers and men of the Meteorological Section of the Royal Engineers, was a pioneer in the investigation of the upper air, an acute observer of meteorological phenomena, and an expert photographer of clouds. Cave was born in 1871 and educated at the famous Oratory School, Edgbaston, and Trinity College, Cambridge. He was elected in 1899 a Fellow of the Royal Meteorological Society, of which he was President in 1913–14 and, a second time, in 1924–25. He died on December 8, 1950 after a short illness.

Cave's outstanding meteorological work began in 1903. Two years earlier a Committee of the British Association, with W. N. Shaw as chairman and W. H. Dines as secretary, had been formed in co-operation with the Royal Meteorological Society to initiate the investigation of the upper atmosphere by means of kites. Shaw in a letter to *The Times* invited the co-operation of volunteer observers—in places where piano wire, miles of which were used in flying the kites, would not cause too much trouble if the kite broke away and trailed the wire across the country. Cave responded, installed his own gear at Ditcham Park, Petersfield, and so began his upper air work which was to extend over many years. The kites and the meteorographs recording pressure, temperature and humidity were designed by W. H. Dines; and so meteorologists in England began to learn actual facts about the lower troposphere. But what about higher levels ? Cave obtained some de Quervain theodolites, set out a base 1¾ miles long and began his fine series of pilot-balloon observations. On January 25, 1907, he sent up the first of the " registering " balloons, carrying the new 1 oz. instrument (2 oz. with its sun-shield) designed and made by W. H. Dines, the records from which provided all our knowledge of the temperature of the high troposphere and stratosphere over the British Isles until the introduction of the radio-sonde 25 years later.

From his observations of upper wind Cave was the first to demonstrate in 1908 the rapid decrease of wind in the stratosphere—in agreement with the theoretical deduction from the fact that in the stratosphere the lowest temperatures occur over the anticyclones, the reverse of conditions in the troposphere. In his Presidential address in 1914 he generously acknowledged the assistance he had received from meteorologists in other countries—to quote his own words, " I can personally testify how English and American, French and German, Russian and Scandinavian are all ready to help each other. There is no jealousy in the upper air; international barriers are broken down." Three years earlier he had hospitably entertained, at Ditcham Park, British and foreign meteorologists and allied scientists attending the meeting of the British Association at Portsmouth (notable for the discussions on the new subject, relativity, opened by E. Cunningham, and on stellar distribution and movement, the " bun " universe, opened by A. S. Eddington). Eleven years later after expressing his regret at the lack of endowment of meteorological science in this country he reminded his audience: " There is no dearth of problems to be solved. Recent advances have left us like Cortez on a peak in Darien, and all the Pacific lies before us to explore."

In addition to his observations at Ditcham Park, Cave made observations with pilot balloons in Barbados. His book, published in 1912, " The structure of the atmosphere in clear weather " was based largely on the results of his own observations, and was illustrated with photographs of models depicting the wind at different levels on occasions of different character of variation with height. In 1926 he published a charming little book " Clouds and other weather phenomena for artists and lovers of nature " which included a number of his own beautiful photographs of clouds. A new edition of this book was issued in 1943.

When meteorologists were first commissioned for service with the army in France in 1915, Cave offered his services and was commissioned as captain. He came to St. Omer, and undertook the instruction of observers transferred mainly from the Artists Rifles and without previous meteorological training of any kind, and their posting at suitable places behind the front. When he had finished this, he returned to England and gave a fuller training at Old Sarum to the recruits needed for France and other theatres of operation. Many of those he trained, among them Sir Robert Watson-Watt, regarded him as their father in meteorology and look back with pleasure to the days when he was initiating them into its truths and its beauties. We, in France, on relatively mediocre commons, received at Christmas 1915 a reminder of his thoughtfulness in the shape of a parcel of delicacies from a notable Piccadilly firm.

Phenology was another aspect of meteorology in which Cave was interested, and he took part in the preparation of the *Phenological Report* of the Royal Meteorological Society from 1926 to 1934.

In the last decades of his life Cave devoted much of his time to archaeology, and, in particular, applied his photographic skill to photograph the roof bosses, often nearly hidden and practically inaccessible, in mediaeval cathedrals and churches. In this he was most successful and his book, published in 1948, was universally acclaimed as an outstanding contribution.

Cave, who had presided at the celebrations of the 75th anniversary of the Royal Meteorological Society, was fortunately able to be present at the centenary meeting and dinner in April 1950, to the great delight of all who knew him. Modesty, courtesy and generosity were his outstanding gifts. Many present and past members of the staff of the Meteorological Office were able by their presence at the memorial service at Brompton Oratory on December 15, to pay a last tribute to a great gentleman and fellow worker in meteorological science and art.

E. GOLD

I am glad to have this opportunity of paying tribute to the memory of Mr. C. J. P. Cave. Although I first knew him on Salisbury Plain in 1918 when he was in charge of the Meteorological Section (Home) of the Royal Engineers, to which I then belonged, it was in 1922 that he appointed me as his scientific assistant. He was interested in a number of meteorological problems and wanted some help in pursuing them at his home at Stoner Hill, Petersfield. Foremost amongst the routine work which he instituted was the observation of atmospherics on a rotating frame aerial by a method which had recently been developed by Mr. (now Sir Robert) Watson-Watt. In the grounds of Stoner Hill, to which he had moved from Ditcham Park a year or two earlier, Mr. Cave had established a meteorological station including Stevenson screen, rain-gauge and rain recorder, Dines anemometer and an evaporation tank; and daily observations were maintained and autographic records tabulated. My keenest recollections are of his daily morning visits to the room in a near-by cottage which served as my office where we would plan the day's work. The friendly warmth of his greeting and the kindly courtesy with which he directed and encouraged my labours were characteristic of his gracious personality. Often at the end of the day we would talk in his study of what we had achieved, and on these occasions he was liberal with stimulating comment and appreciation. I shall always be grateful that it was my privilege to begin my meteorological career under so wise and sympathetic a guide and counsellor.

S. P. PETERS

ESSAY ON FRONTOGENESIS AND FRONTOLYSIS

By H. H. LAMB, M.A.

This essay was mainly written during a relatively slack period at an aviation station some time after the war. Although it is not a research paper, it has been put forward as a useful practical summary which brings together a number of points of general interest.

Part I

Introductory.—The theoretical treatment of frontogenesis and frontolysis due to Bergeron[1] and Petterssen[2] has not led to such systematic use in the technique of weather analysis and forecasting as the importance of the subject might suggest. Regions of confluence leading to increasing thermal gradient are, however, watched for on thickness charts, where these are in use, and their significance in relation to the occurrence of jet streams in the upper troposphere and for future developments down-wind in the developing jet is increasingly appreciated; but fronts are often entered on the charts for quite other reasons.

Frontolysis has been largely passed over in the meteorological literature as a mere counterpart of frontogenesis. Fronts often disappear from the charts for no clearly understood or expressed reason, or only because they have moved into regions with which the forecaster is little concerned.

The object of this essay is therefore to give a little further consideration to these problems and bring them into some perspective. We need not concern ourselves with precise criteria for the existence of a front, since we propose rather to discuss practical illustrations of the processes of formation and decay and their implications in the case of fronts which are generally accepted. The exact nature and the complex, finer structure of fronts are still a matter for investigation and research. Meanwhile we may use Douglas's definition of a front as " essentially a line of discontinuity in the horizontal distribution of temperature, with an associated discontinuity of pressure and wind".

The final criterion for entry or omission of a front from the map seems likely to remain somewhat arbitrary and dependent upon considerations of usefulness, but it needs emphasizing that when simplification of a complex map is desired this may sometimes be permissibly achieved by omission of weak systems (and weak portions of formerly continuous frontal systems) but never by distortion to achieve artificial conformity with a text-book model. Attention given to actual frontal shapes, arising with various flow patterns and distributions of velocity, proves very helpful in interpreting isolated or vestigial weather phenomena.

Petterssen, distinguishing between the four possible types of fluid motion—translation, rotation, divergence or convergence (on a point), and a deformation —uses the picture of the typical deformation field reproduced in Fig. 1, and defines frontogenesis and frontolysis in terms of it[3]: " We consider a scalar quantiy S which has a continuous distribution in the horizontal plane (x, y). S may be represented by its equiscalar curves on a map. When time t varies the S-curve (e.g. isotherms) will, in general, move relative to the co-ordinates of the chart. We then say that *we have frontogenesis if the S-curves move in such a way that they tend to create a discontinuity along a line in the field.*" The reverse case is frontolysis.

The diagram is properly applied to stream-lines, but if considered in terms of hypothetical isobaric flow the important additional frontogenetic or frontolytic influence of ageostrophic motions must be allowed for.

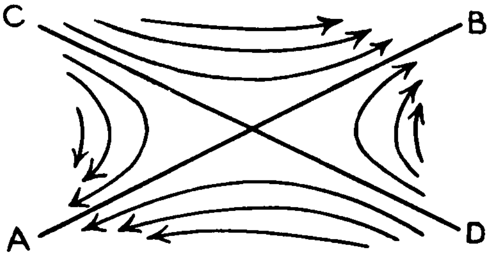

FIG. 1—DEFORMATION FIELD
(Stream-lines)

AB and CD (Fig. 1) are the axes of inflow and outflow respectively in a normal col circulation. Isotherms ranged parallel with AB in an initially weak thermal gradient will be brought progressively closer to one another along the line of the inflow axis AB, which therefore becomes a line of frontogenesis if this circulation persists. In the end widely different air samples from far distant sources at C and D will be brought towards one another near the line AB. Convergent (ageostrophic) motion is, however, needed to produce an actual discontinuity within the narrowing frontal zone; and the associated development of upgliding and undercutting will ultimately be spontaneous.

Isotherms initially parallel to CD would of course be drawn apart towards A and B, from which we see that CD is a frontolytic line.

Temperature fields in which the isotherms have various other orientations are progressively swung into alignment with AB or CD according as the initial angle between isotherms and inflow axis is less or greater than a critical value, which itself depends on the angle between the axes of the col; the effect of the col is accordingly either frontogenetic or frontolytic.

A significant outcome of the deformation process is seen when a really strong thermal gradient can be produced along the axis AB between, say, a cold source at C and a warm source at D (northern hemisphere). A strong thermal wind then develops in the same direction as the surface winds in the right-hand branch of the confluence, towards B. In this region jet streams are generated in the upper troposphere, though the strongest development of the jet may culminate some 1,000–2,000 miles down-wind as the surface wind strengthens in association with travelling cyclonic circulations which develop from waves on the sharpened surface front.

Nevertheless frontogenetic cols can seldom stay long enough in one place to produce a fully fledged front where none was before. Their main importance for the surface frontal pattern is in sharpening already existing weak fronts, old occlusions and frontal belts containing more than one former frontal system until they are once more strong, simple fronts capable of major activity.

For the actual birth of the more numerous fronts shown on our charts we must probably call in an altogether different process, such as that put forward by Refsdal[4] or that represented by Sawyer's occlusion breakaway depressions (see later).

We must also notice that the normal horizontal distribution of wind velocities in a depression, with light winds near the periphery, twists the frontal system forward near the centre and back near the edge of the storm in such a way that the trailing front approaches the inflow axis of the adjacent col. This means that the frontolytic case seldom arises in practice. Frontolysis must commonly be explained in other terms.

Frontogenesis.—The frontogenetic col is most effective if the axis of inflow lies in a geographical belt where a steep gradient of temperature of the earth's surface induces a corresponding zone of quick transition in the overlying air.

The most important geographical belts favouring frontogenesis* are:—

(*a*) In the North Atlantic Ocean off the east coasts of North America and Greenland, near the boundary of the Polar Ice Labrador Current and Gulf Stream waters. The cold surface west of the boundary is far more extensive in winter, when the American continent is cold, than in summer.

(*b*) The corresponding belt in the North Pacific Ocean off the coast of Asia to the Aleutians, to which similar remarks apply.

(*c*) From late summer through autumn the thermal gradient, around the fringe of the permanent ice in the Polar Basin along the north coast of Asia and North America, rivals (*a*) and (*b*) in importance.

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*The basis of these ideas will be found in Bergeron's "Richtlinien einer dynamischen Klimatologie"[5].

(*d*) In late autumn through winter, as the continents cool down particularly in their eastern portions, (*c*) tends to be replaced by two belts dipping south-eastwards into the heart of the great continents:

(i) through Alberta along the flank of the northern Rockies, where mild air from the Pacific Coast meets the snow-covered interior of the continent;

(ii) a rather less definite north-west to south-east line near the White Sea and north Urals where mild air from the Atlantic and land-locked seas of Europe reaches the main continental interior with its winter snow cover. This line of thermal contrast is more fitfully maintained than (i), being itself considerably dependent on the patterns of air circulation prevailing. Occasionally advection around the Asiatic anticyclone carries warm air east along the north coast and restores belt (*c*) even in the depth of winter.

(*e*) In spring and autumn transitional periods (i) the Baltic Sea and (ii) the St. Lawrence Valley mark important zones of contrast between cold largely snow-covered regions to the north and warmer lands to the south; (ii) has also some importance at other seasons.

(*f*) In winter and early spring a belt of strong thermal gradient runs from the coast of north-west Africa through the Mediterranean across Turkey and the Persian highlands finally becoming weaker and more variable in position towards Mongolia and Tibet. The corresponding feature of deep winter in the western hemisphere is a prolongation of belt (*a*) into the Gulf of Mexico.

(*g*) In the southern hemisphere the main belt is that which surrounds the Antarctic continent and, in winter, the edge of the pack-ice.

(*h*) Subsidiary frontogenetic zones occur near the coasts of the warmer southern continents at suitable seasons of the year.

The most favourable circumstances of all for frontogenesis occur when an already existing air-mass boundary (or old frontal system) moves into one of these geographical belts and happens to come under the influence of a suitably orientated frontogenetic col there (see also Rodewald[6]).

Climatological charts show that belt (*a*) in the western Atlantic corresponds roughly to the inflow axis of the col in the mean winter pressure distribution between the Azores–Bermuda high and the north Canadian anticyclone and between the Iceland low and low pressure in the Mexican Gulf. This means that the frontogenetic pattern repeatedly occurs when cold, continental winter anticyclones move south-east towards the Atlantic seaboard of North America behind the occluded fronts of depressions which have passed out on to the Atlantic. These old occluded fronts are then sharpened and transformed by the frontogenetic deformation field into the so-called Atlantic polar front, on which new depression families arise.

Similar sequences take place off the east coast of Asia and less regularly in other parts of the world.

It is interesting to watch what happens when a frontogenetic col appears in a single air mass over one of these geographical transition belts favourable to frontogenesis. Embryonic frontal phenomena begin to appear. Sheets of thin altostratus or altocumulus start to form as the convergence in the horizontal wind field forces upgliding at any minor surfaces of discontinuity, even former subsidence surfaces, existing aloft. Stratus sheets may be similarly formed in the lower levels. Slight rain or drizzle sometimes results. All this may happen before the surface temperatures and humidities have developed any sharp discontinuity. And then, in most cases, the movement of distant pressure systems causes the col to shift; the pattern of flow ceases to be favourable for front formation, and the frontal phenomena, that have been appearing, dissipate without having come to anything. Even in the most likely geographical regions the frontogenetic circulation pattern must persist for many hours if a front is to be formed. The length of time required is a variable quantity depending on wind components along the axis of inflow in the opposing air streams as well as on the physical properties of the air involved.

It is clear that not many fronts would be formed in the atmosphere if the process described by the theoretical deformation-field diagram (Fig. 1) were the only one capable of creating a front. Too great a coincidence of favourable circumstances is required.

The number of fronts shown on the daily weather maps of every forecasting office compels us to consider what alternative processes may lead to front formation.

The most prolific process giving new discontinuity lines in the horizontal field of flow is believed to be that represented by the following sequence: bent-back occlusion and re-occlusion of pseudo warm sector, followed by the same process again, often repeated several times in one depression. This sequence, illustrated by the diagrams in Fig. 2, due to Refsdal[4], is a fertile source of secondary cold fronts. The successive bent-back occlusions may be treated as secondary cold fronts at quite an early stage in their history. Occlusions, across which the temperature contrast is in the reverse sense, tend to die away for obvious reasons when bent back around the rear of the depression. Later association with a frontogenetic col will be liable to convert any secondary front into a front of major importance.

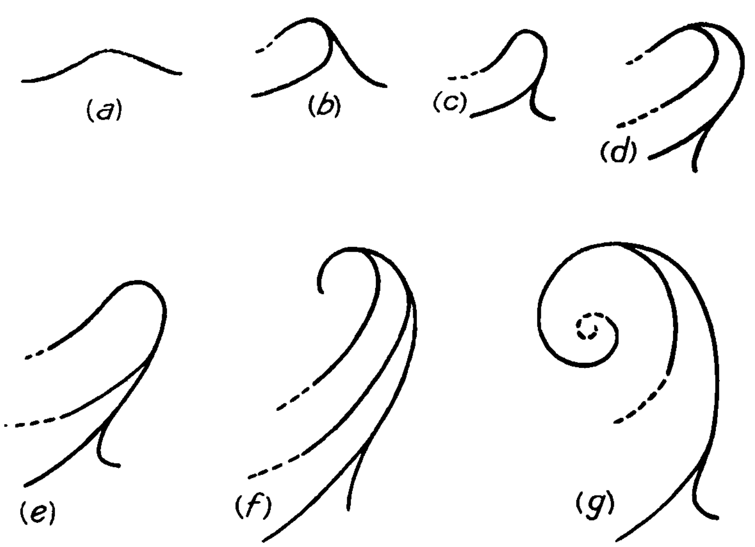


FIG. 2—DEVELOPING FRONTAL PATTERN IN A MAJOR DEPRESSION (after Refsdal)

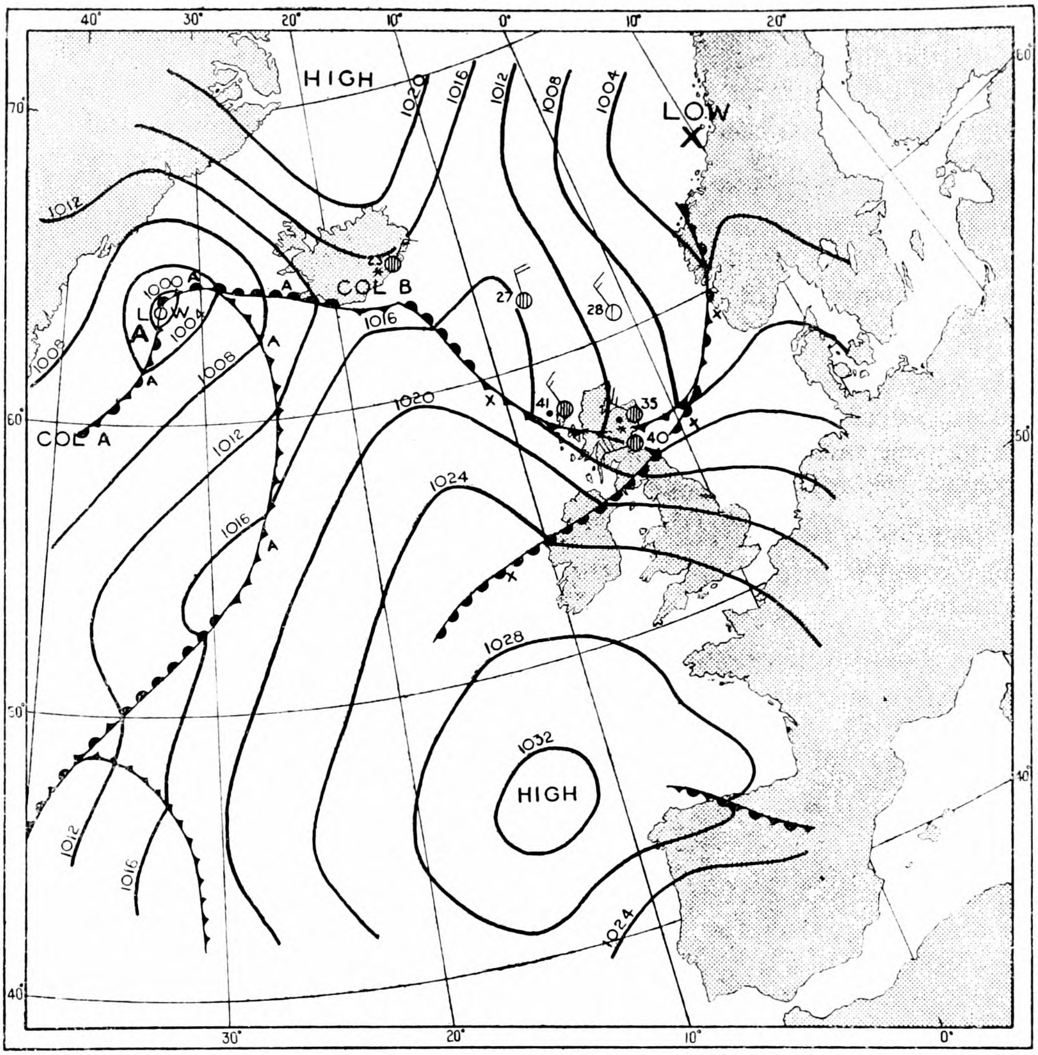
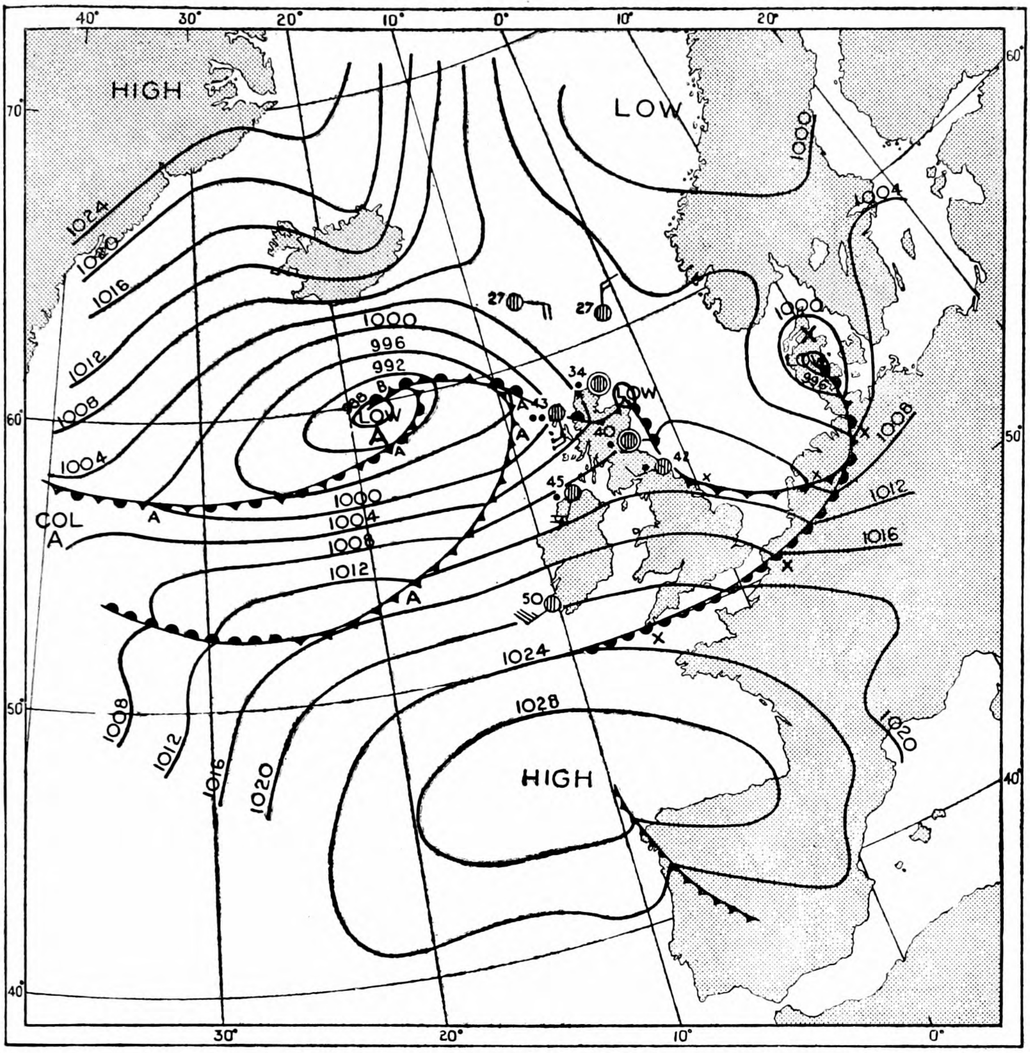


FIG. 3—SYNOPTIC CHART, 0600 G.M.T., FEBRUARY 22, 1946

Conventional analysis tends to pick upon the major fronts and ignore the minor discontinuities produced by this process. Difficulties arise with some old depressions in which all the fronts are rather minor, and all have a more or less equal claim to recognition.

A case of this kind arose on February 22–25, 1946, (Figs. 3–6). Space forbids the entry of more than a few illustrative observations at points of interest, insufficient for actual proof. Conventional analysis confined to a single warm front, cold front and occlusion entirely failed to explain the patterns of wind and weather in the depression A as it developed and moved across the British Isles. Considerable areas experienced continued warm-sector-like conditions after one or two wind veers and rising pressure had set in. The depression might reasonably have been treated as more or less non-frontal, with intermittent rain and drizzle and local clearances over its entire area. Individual stations where detail was important might nevertheless trace three or four successive weak fronts passing and bringing a final clearance only when the veering wind at last reached a point giving some orographic shelter.


40°
30°
20°
10°
0°
10°
20°
HIGH
LOW
70°
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1000
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1024
1020
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1012
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1004
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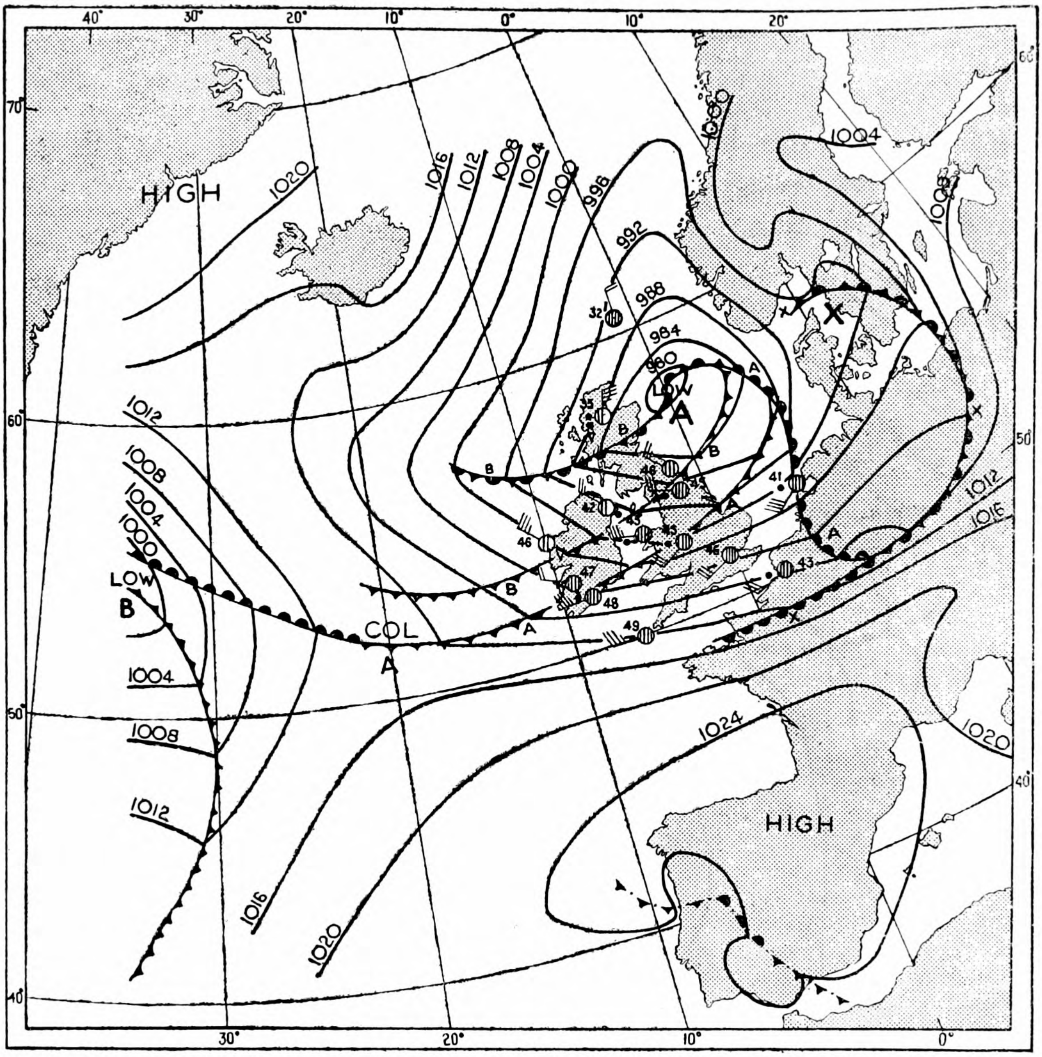
996
992
B
LOW
A
A
27
27
34
LOW
43
40
42
45
996
1000
1008
COL
A
1000
1004
1008
1012
1012
1016
A
A
50
1024
1028
HIGH
1008
1012
1016
1020
1020
60°
50°
40°
50°
40°
30°
20°
10°
0°

FIG. 4—SYNOPTIC CHART, 1800 G.M.T., FEBRUARY 22, 1946

Low A is seen, already partly occluded and with a depth of 1000 mb., west of Iceland on the morning of the 22nd (Fig. 3). In the following 24 hours the centre moved quickly east-south-east into the North Sea, the original occlusion A became secondary cold front B on the map for the 23rd (Fig. 5), and in the course of re-occlusion the centre deepened to 980 mb., producing a long new frontal line, occlusion B, which already showed signs of repeating the process. The centre deepened further to 968 mb. when it approached Denmark on the evening of the 23rd and as the second pseudo warm sector occluded. Ultimately occlusion X of the former Scandinavian low was swept around the rear of low A as a further secondary cold front over Denmark when the deep centre moved into the Baltic. With this final development completed, the centre began to fill up, and, by the evening of the 25th, it was represented only by several shallow centres of 1008 mb. along a single occlusion coiled up over the Baltic States, south Sweden and central Russia (see Fig. 6).

Figs. 3 and 4 further show how occlusion A was not only bent back but necessarily rotated into alignment with the inflow axis of col A over the Atlantic


40°
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40°
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1004
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992
988
984
980
LOW
A
B
X
1004
1008
1012
1016
1020
LOW
B
1012
1008
1004
1000
COL
A
1004
1008
1012
1016
1020
1024
HIGH
32
41
42
43
46
47
48
49
30°
20°
10°
0°

FIG. 5—SYNOPTIC CHART, 0600 G.M.T., FEBRUARY 23, 1946

south-east of Greenland and thereby came under the influence of the frontogenetic effect of the deformation field, which seems to have prolonged the front to the westward as time went on. Fig. 5 shows the primary cold front A likewise brought into line with the frontogenetic axis of the col as a natural consequence of the circulation pattern. We see too how a normal development of the circulation is quite unlikely to produce a frontolytic orientation of the front in the col.

Fig. 6, marking the end of the sequence, is an interesting example of the fertility of the occlusion process at different points along the subtropical-subpolar air-mass boundary in producing a welter of new, offshoot fronts, any one of which may later be subjected to the sharpening process of a frontogenetic deformation field. The occlusion marked A on this map is already the product of closing together (consolidation) of a bunch of occlusions (A, B and X) developed in the earlier stages of the life history of depression A. Consolidations of this kind are frequent, but complete amalgamation of the successive fronts requires ageostrophic motion and is not always achieved. Cold front C was

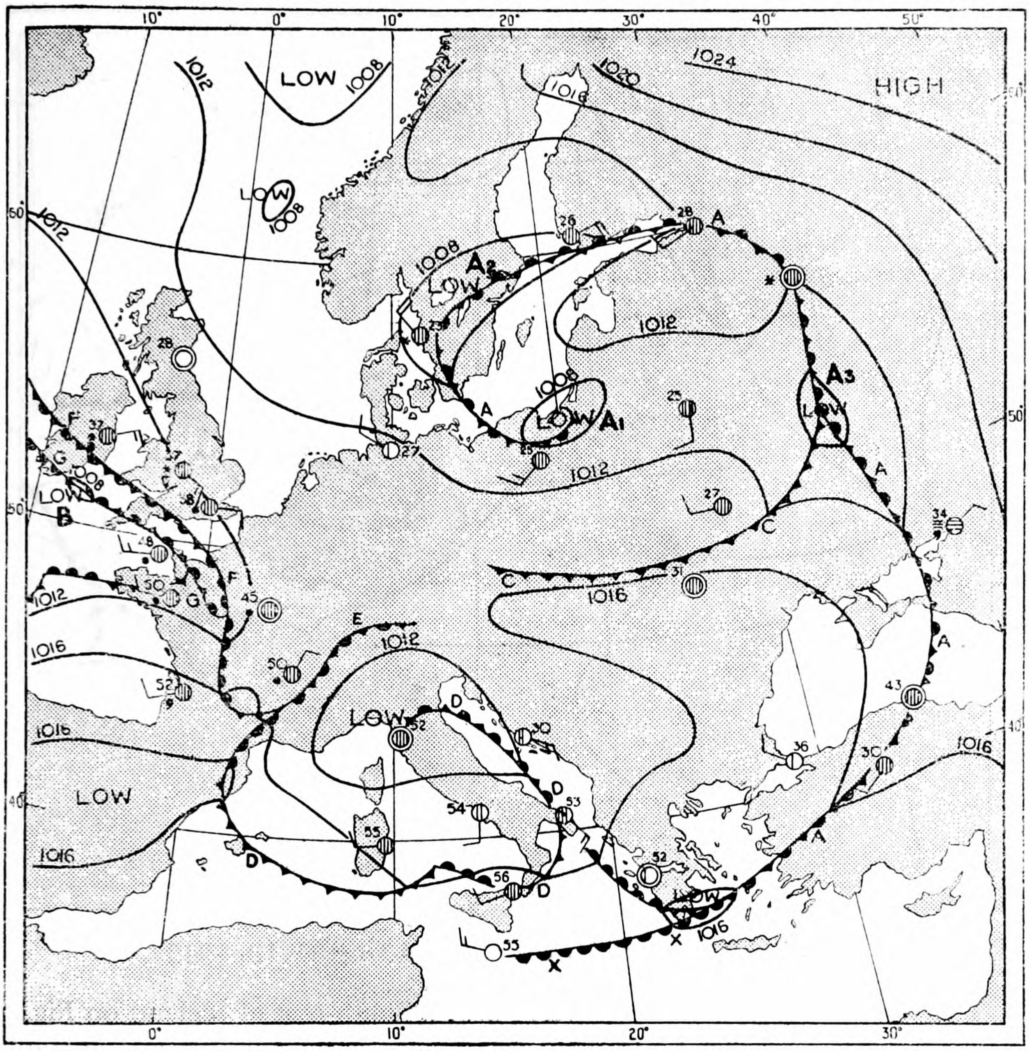
10°
0°
10°
20°
30°
40°
50°
LOW
1008
1012
LOW
1008
HIGH
1024
1020
1016
1012
A
A₂
LOW
1008
1012
A₃
LOW
A
A
1008
LOW
A₁
1012
1012
C
C
1016
A
1016
E
1012
F
G
LOW
B
1008
F
G
1012
1016
1016
LOW
D
D
D
D
LOW
1016
1016
X
X
1016
50°
50°
40°
40°
0°
10°
20°
30°

FIG. 6—SYNOPTIC CHART, 1800 G.M.T., FEBRUARY 25, 1946

formerly an extraneous system drawn into the circulation of the rear side of low A from Scandinavia and now helps the development of a new depression over Russia with a warm sector formed between the old warm occlusion A and the cold front C; this system moved south-east towards the Caspian Sea with renewed intensity of precipitation. Occlusions D, E, F and G are new derivatives of the activity along the same parent front, and the occlusions F and G are in process of being closed together into a single, sharp front by the pattern of winds over northern France and southern England. Ageostrophic components are evident. The subsequent activity on the sharpened front between the mild Atlantic air masses to the south and the Arctic air mass with freezing temperatures to the north of the confluence gave one of the heaviest snowfalls in recent years in Kent.

The spotting of this situation, which will squeeze together parallel fronts (simplifying the map) or sharpen and energize the frontal belt, is an important use of the deformation-field pattern (Fig. 1). The building up of potential energy and quickening of upgliding motions with increased rainfall commonly take 24–48 hours to mature.

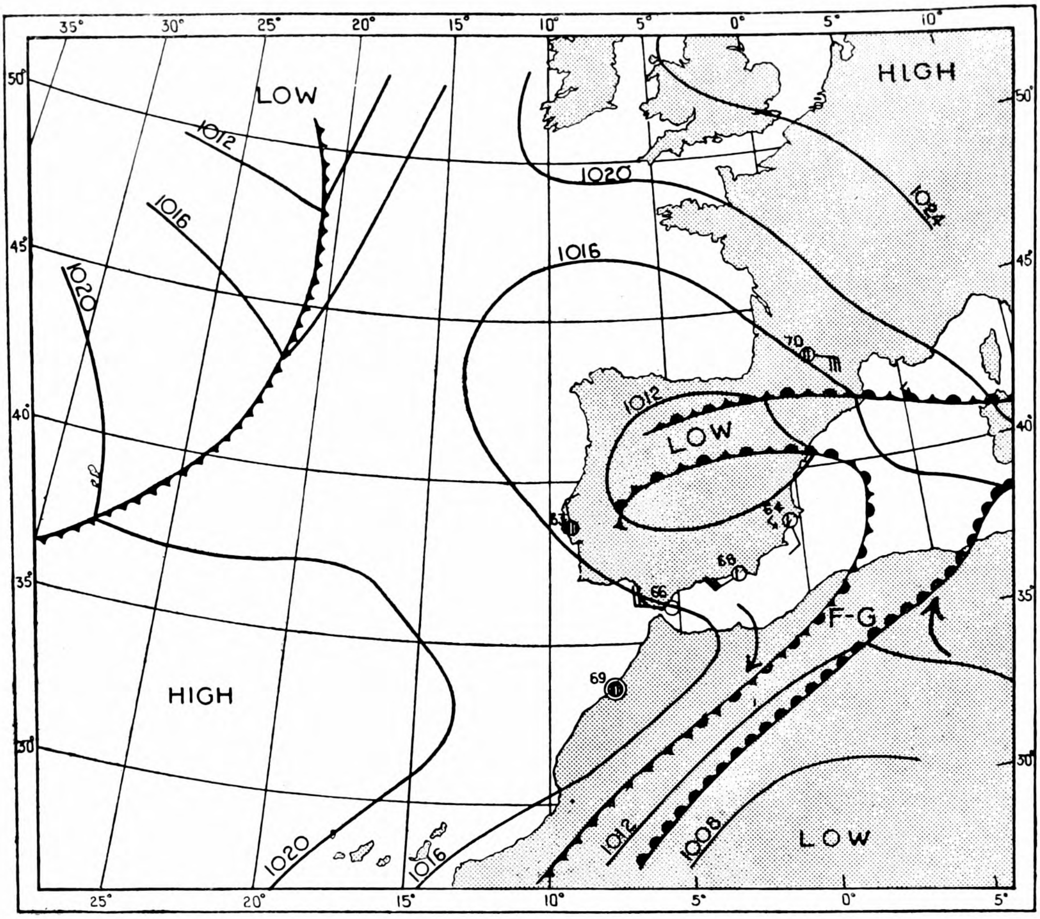

FIG. 7—SYNOPTIC CHART, 0000 G.M.T., JUNE 19, 1945

The warm-front wave disturbance forming south-east of Iceland on Fig. 3, rather as a break away running ahead of the depression A and travelling south-east to Scotland during the 22nd, may be looked upon as an example of this action in the case of the frontogenetic col B. The south-westerly air stream (tropical maritime air) which gave a temperature of 43°F. at Vestmannaeyjar, south Iceland, and the arctic air stream with temperatures around 23°F. met from directly opposite directions at this section of the front. The warm-front wave, which appeared, travelled quickly south-east in the strong thermal gradient, bringing rain and sleet far ahead of the main depression.

Break-away depressions forming at the point of occlusion and running ahead of the parent low, studied by Sawyer[7], commonly produce one long new frontal line upon our maps by prolonging the occlusion. This process is therefore another source of new fronts.

Another interesting frontogenetic sequence occurred over north-west Africa and the regions to the north on June 19, 1945.

The chart for 0000 on the 19th (Fig. 7) shows a rather complex situation with parallel fronts over north Africa associated with the very old depression over Spain. Pressure gradients are weak but a frontogenetic col is marked on the chart near Algiers, and the temperature contrasts between the air masses

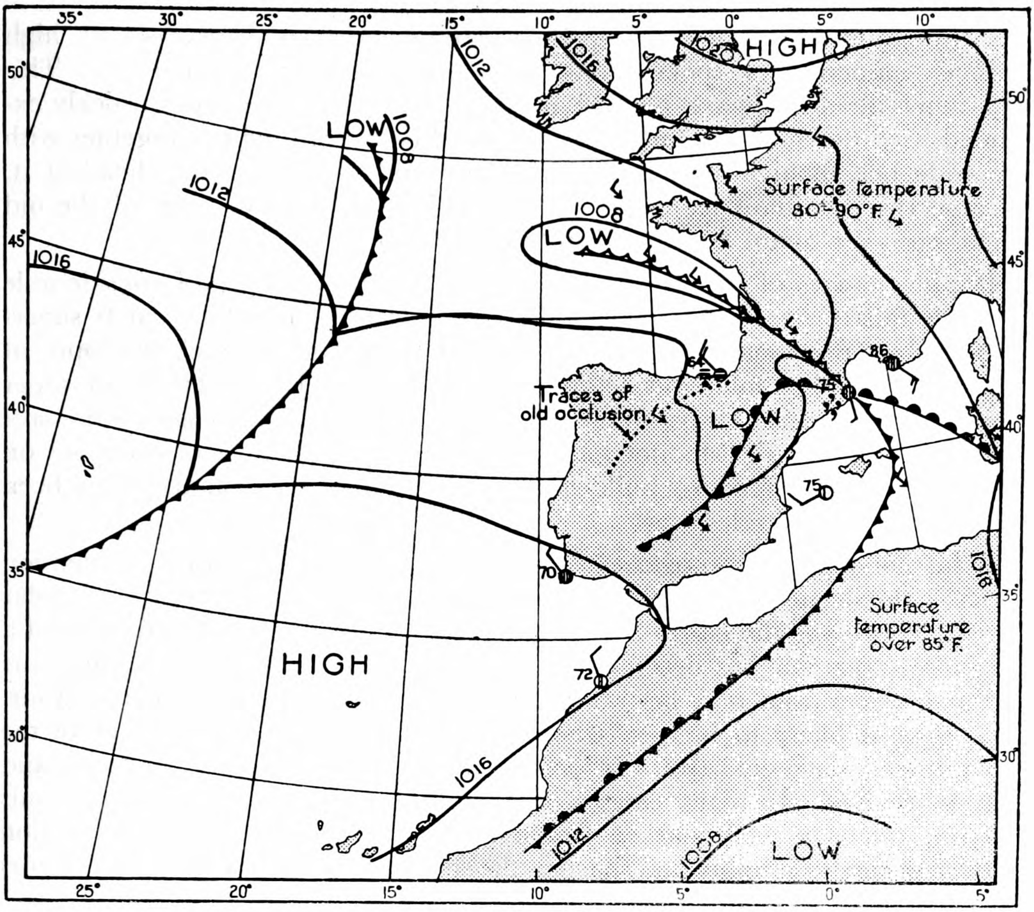
35°
30°
25°
20°
15°
10°
5°
0°
5°
10°
50°
45°
40°
35°
30°
HIGH
1016
1012
LOW
1008
1012
1016
1008
LOW
Surface temperature 80°-90°F
Traces of old occlusion
LOW
64
86
75
75
70
72
1018
Surface temperature over 85°F
HIGH
1016
1012
1008
LOW
25°
20°
15°
10°
5°
0°
5°

FIG. 8—SYNOPTIC CHART, 1200 G.M.T., JUNE 19, 1945

approaching one another at this point are great. By 1200 on the same day (Fig. 8) the situation in the frontogenetic belt has been reduced to a single sharp front. The resulting simple warm sector over the western Mediterranean continues northwards aloft as a broad expanse of altocumulus castellatus clouds over France; and its trough-line, the upper cold front over the Bay of Biscay, is producing a sharp trough in the isobars over the Bay. Aircraft reports indicated conditions in the lifted air mass getting progressively more stable westwards to tail out as a thin sheet of altocumulus, or high stratocumulus, about the 8,000-ft. level in 9°W. over the Bay. B.O.A.C. and K.L.M. aircraft flying along the Atlas mountains *en route* from Malta to Rabat reported severe thunderstorms in frontal medium cloud in the region where the sharpened front is shown, whilst the general increase in activity of the depression system is demonstrated by the much greater number of reports of lightning and atmospherics shown at 1200 G.M.T. on the 19th, than at the previous midnight (compare Figs. 7 and 8). Recent thunderstorms were reported on both charts but none at the hour of obsevation at the stations used. The transformation of the frontal pattern went one stage further during the afternoon and evening of the 19th. The westerly breezes developing behind the pressure trough associated with the upper cold front over the Bay of Biscay brought in cool Atlantic air to south-west France. The trough now corresponded to the main temperature contrast on the surface map between the cool oceanic air (polar maritime) and the strongly heated European and African air masses with high surface temperatures (polar continental and tropical continental). This situation is already apparent in Fig. 8. As a result the upper front quickly extended itself down to the surface as a normal cold front, which, together with the wide belt of high-level instability cloud and thunderstorms ahead of it, became the dominant feature of the map, leaving merely traces of the old occlusions over Spain as relics of little consequence.

Rapid changes of the isobar pattern, under the influence of considerable pressure falls probably associated with the release of instability aloft superimposed on a previously flat situation, made the stages of this quick development (Figs. 7–8) hard to follow in detail. Nevertheless this conversion of an upper front to a surface front is by no means unique. British meteorologists who have been stationed in the Mediterranean speak of a fair number of occasions on which fronts appeared to " build downwards " and some instances have been noted in higher latitudes.

A further type of frontogenesis to which Mr. Douglas has drawn attention is liable to occur in southerly or south-westerly sweeps of returning polar maritime air over the North Atlantic. When the southernmost extremity of a tongue of polar air has become very shallow and considerably modified, the effective warm front may be transferred north to the limit of deeper cold air. This is most likely to happen where an old, weak front, such as one of the trailing secondary cold fronts of depression A (Figs. 3–6), already exists and may be revived. In many cases of this kind, however, vestiges of both fronts remain, unless a well marked frontogenetic convergence and deformation pattern occurs to simplify and sharpen the situation, or the geographical factors are particularly favourable.

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A SYSTEMATIC SMOOTHING TECHNIQUE USEFUL IN THE CONSTRUCTION OF MARINE CLIMATOLOGICAL CHARTS

By T. H. KIRK, B.Sc.

Current meteorological atlases for ocean areas include charts showing the spatial variation of monthly mean values of different climatic elements for each month of the year, the mean values being derived from ships' observations made over a long period of years. In preparing these charts it is usual to group the observations in each 2° square and to assume that the mean value applies to the centre point. In practice larger or smaller areas (e.g. 5° or 1° squares) may be used depending on the number of observations available. A refinement of this procedure consists of grouping observations at their centroid instead of at the centre of the square.

Whatever variation is used the next task is to smooth the mean values depicted on each monthly chart. Current practice consists of smoothing spatially the values on each chart while taking care that no great inconsistency arises between successive charts. This is not easily achieved where observations are sparse, and, without some knowledge of the differences of seasonal change from place to place, it is indeed difficult to assess consistency. In the construction of "Monthly sea-surface temperatures of North Atlantic Ocean"* the following method was found useful in helping to distinguish between casual and significant detail. A series of derived charts was drawn in which the position of a particular isotherm was depicted for each month on the same chart. Detail which violated the steady progression of sea temperature throughout the year was smoothed. The application of this method calls for considerable caution, especially for those mean isopleths near maximum and minimum values. It is important not to alter the type of annual variation characteristic of any particular place. The limitations of this procedure are apparent, though its usefulness in practice is sufficient evidence that more attention should be paid to the time sequence.

It is possible to smooth the data systematically with respect to both space and time by applying the method of harmonic analysis to the raw data, i.e. to the calculated monthly mean values regarded as a time sequence. The following parameters are then obtained for each square:—

a_0, the annual mean,
a_1, the amplitude of the annual component,
a_2, the amplitude of the semi-annual component,
A_1, the phase of the annual component, and
A_2, the phase of the semi-annual component.

It is usually neither necessary nor justifiable to work with additional components. The climatic element, T, may then be expressed in the form:—

$$T = a_0 + a_1 \sin (t + A_1) + a_2 \sin (2t + A_2),$$

t (time) taking values at 30° intervals from 0° to 330°.

The parameters a_0, a_1, a_2, A_1, A_2 define the element T, and, once evaluated, replace the raw data. To ensure a spatial consistency, charts are constructed to show the distribution of each of the harmonic parameters, the isopleths being smoothed by eye or according to some arbitrary rule. These charts of smoothed values of the harmonic parameters afford all the information that is required of the element T and depict it in a highly condensed form. Using the charts it is simple to write down an analytical expression for T at any place.

Although this method of representation may meet the needs of the scientific worker it is not suitable for the mariner and those others who require a mean or average picture at successive intervals of time. Charts at monthly intervals are easily constructed by calculating T from the smoothed values, applying the formula:—

$$T = a_0 + a_1 \sin (t + A_1) + a_2 \sin (2t + A_2)$$

for as many positions as may be considered necessary.

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*London, Meteorological Office, 1949.

At the suggestion of Mr. Durst this method has been applied to construct a chart of mean monthly sea-surface temperature of the North Atlantic Ocean for a specimen month (May). The satisfactory result obtained demonstrates that the technique will be useful in eliminating inconsistencies in the preparation of monthly mean charts of sea-surface temperature.

It is appreciated that the method has been employed in the most favourable conditions. Good mean values of sea-surface temperature can be obtained from relatively few observations and few areas have a density of observations comparable with that of the North Atlantic Ocean. The application to other climatic elements and to other regions depends on the density of the observations in both space and time. As more data become available the method should be useful at least for ensuring that a sequence of charts will show a reasonably true annual variation at every place.

EXPOSURE OF EARTH THERMOMETERS

By A. J. WHITEN

For some time past there have been doubts as to the suitability of steel tubes for the exposure of thermometers below the surface of the earth.

To determine whether there was any systematic error in the readings of thermometers so exposed, two pairs of sheathed, lagged thermometers have been installed at Cuddington, Surrey, at depths of 1 ft. and 4 ft. One pair are in ordinary steel tubes, while the others are suspended in brass cells, to which access is obtained through lengths of rubber tube, such as is used for radiator connexions in internal combustion engines.

The interior diameter of these tubes is somewhat greater than that of the steel tubes, being 2 in., so as to permit the thermometer to drop freely without binding on the sides. To check any tendency to convection in the tube, a " collar ", composed of two pieces of hose of smaller diameter, fitted telescopically, is held between rubber rings round the sheath of each thermometer (see photograph facing p. 64).

These instruments form part of an installation of ten thermometers and a themograph in an enclosed patch of grass 3 ft. square (see photograph facing p. iii of cover), so there is little question of differences on account of siting.

The thermometers, which were supplied by the Meteorological Office, are certified to have errors not greater than ±0·1°F.

The first readings were taken on November 9, 1948, and temperatures have been recorded daily ever since, at 0900 G.M.T. At this hour all the instruments are in shade, the first sunlight falling on the steel tubes shortly after 0930 at midsummer.

During the two winters while this record has been kept, there has been little or no difference between the temperatures recorded by the two pairs of thermometers, but by the beginning of April each year, small but persistent differences became apparent, which increased to as much as 1·5°F. at times during spring and summer.

The greatest differences occurred at the end of each period of sharply rising temperature, the thermometers in the steel tubes always reading rather higher than those in rubber.

The greatest differences during 1949 were:—

June 14, 1·4°F.—This followed a spell of seven days with minima over 50°F., the maximum on the 13th being 79°F. with only 0·02in. of rain on the 13th. The previous five days showed some 30 hr. of sunshine, with less than 1 hr. on the previous day.

July 6, 7, and 8, with 1·5°, 1·4°, and 1·4°F. respectively.—This spell came after ten days with maxima mostly in the eighties and nineties, though during these three days 75°F. was the highest recorded in the screen. Minima had been between 47° and 61°F. There had been only 0·01 in. of rain and the five days' sunshine amounted to over 60 hr., though there was singularly little during the three days under review.

In 1950, up to the time of writing (mid July), most of the greatest differences were between June 7 and 14, when the average was 1·45°F. with a range between 1·2° and 1·7°F. During this time maxima ranged from 70° to 84°F., with minima mostly in the upper fifties, the previous few days having been somewhat cooler. There was 0·25 in. rain during these days, and on the 3rd there had been 0·83 in. During the preceding three days no sunshine was recorded, but there were 68 hr. during this week.

This was followed five days later by a difference of 1·6°F. on June 19, when maxima had been 71°F. or lower for three days and minima had been between 46° and 54°F. During the preceding five days there had been 1·5 in. rain and only 26 hr. sunshine.

With the heat of late summer in 1949 the differences diminished as the temperatures in the rubber tubes came closer to those in the steel. By the end of September these differences were only one or two tenths, and remained thus until the middle of October, when the steel tubes were showing slightly lower temperatures than the rubber. Throughout the autumn, differences were considerably less than during spring and early summer, only two instances of 1°F. being recorded, on November 22 and 25, which fell at the end of ten days during which maxima were high for the time of the year (upper forties and fifties), but grass minima sometimes approached frost. During these days there was little or no sunshine (10 hours) and 1·5 in. of rain. By December the differences had dwindled to insignificance, and did not reappear until April.

Throughout, as might be expected, differences at 4 ft. lagged some 2–3 days behind those at 1 ft., and were rather less than half their magnitude; but there was another point of some interest in the readings of the 4-ft. thermometers.

After the rubber tubes had been installed, with much hard labour involving digging a yard-square pit four feet deep in very heavy clay, it became apparent that the junction between the brass and the rubber was not completely watertight, and heavy rain found its way into this tube. There being no leak at the base of the brass cell, the water lay to a depth of some 10 in. at the bottom of the tube, and could only be removed by soaking it out with a piece of muslin on the end of a five-foot pole (except when I was able to borrow a suction pump from a friendly garage owner). As this operation was usually followed within 36 hr. by more heavy rain, it came to be left for rather long intervals, as it did not seem that the presence of the water would have any appreciable effect on temperature which changes so slowly at all times, once it has reached thermal equilibrium with its environment. It soon became apparent, however, that after heavy rain (¼ in. or more in a day) this thermometer tended to read about 0·2°F. higher than it should. As these effects were noted only in winter, when the rain water might be expected to be warmer than the earth and the surface to be colder than the depths, it seems that the rain carries some of its heat to a depth of at least 4 ft., even through heavy clay.

A few weeks after having arrived at this conclusion, I was interested to read in *Weather** that the same deduction had been made from temperatures observed by a completely different method.

TEMPERATURES UNDER DUTCH LIGHTS

By L. P. SMITH, B.A.

During the early months of 1949 and 1950 readings of mercury-in-steel distant-reading thermographs have been taken at Botley Experimental Station (near Southampton). The bulbs were placed at a height of 4–5 in. under Dutch lights (a cold frame) of 5-light and 2-light size, and at the same height in the open. The bulbs were screened from direct radiation and no crops were grown in the vicinity. The soil under the lights was not watered. Examination of the charts, part of one of which is reproduced in Fig. 1, shows the following results.

Rise in minimum temperature under the lights.—There is no evidence of any significant difference between the minimum temperatures in the 5-light and 2-light frames during February. As the season progresses there is an increasing tendency for the minimum temperature in the 2-light frame to be the higher. As, however, the degree of accuracy of the thermographs is of the order of ±1°F., and as the exact siting of the themometer within the frame may have an effect of the same order, this cannot be regarded as a firm conclusion.

TABLE I—MEAN DIFFERENCE BETWEEN MINIMUM TEMPERATURES IN 5-LIGHT AND 2-LIGHT FRAMES

	February	March 1–15	March 16–31	April	May	June
Mean Difference (°F.) ...	0·0	0·6	1·1	1·0	2·0	3·9
No. of comparisons ...	26	26	27	11	6	7

TABLE II—FREQUENCY OF RISES OF DIFFERENT VALUES

	(Mean of minima under lights)—(minimum in open), °F.												Total	Mean
	<0	0, 0·5	1, 1·5	2, 2·5	3, 3·5	4, 4·5	5, 5·5	6, 6·5	7, 7·5	8, 8·5	9, 9·5	10, 10·5		
	number of occasions													°F.
Feb.	3	2	4	6	4	7	4	3	...	...	...	...	33	2·9
Mar.	2	7	1	9	7	9	5	5	3	3	3	...	54	4·0
Apr.	0	3	4	0	0	2	2	0	2	2	1	1	17	4·9

TABLE III—FREQUENCY OF MINIMUM TEMPERATURES

		>32°F.	⩽32°F.	⩽29°F.	⩽25°F.	Lowest minimum
		number of occasions				°F.
Feb.	Under lights ...	21	12	4	0	28 (twice)
	In open ...	15	18	14	6	22
Mar.	Under lights ...	48	6	2	...	26·5
	In open ...	38	16	10	...	22·5

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*BALLS, L.; Soil temperatures on tap. *Weather*, *London*, 5, 1950, p. 40.

The frequency of rise of temperature taking the mean of 5-light and 2-light minima is given in Table II, and the frequency of minimum temperatures in various ranges in February and March is given in Table III.

Rises during February.—The frequency is given in the first line of Table II, the range of difference being from −2·5° to +6·5°F. The frequency of actual minimum temperatures is given in Table III. The figures suggest that, although the average gain in any empty frame is not large, the number of frosts and, especially, of severe frosts is decreased considerably.

Rises during March.—The frequency is given in the second line of Table II, the range of difference being from −0·5° to +9·5°F The rise in minimum temperature appears to be related to the number of hours of sunlight during the preceding day, as shown in Table IV.

TABLE IV—RELATION BETWEEN SUNSHINE DURING PREVIOUS DAY AND RISE IN MINIMUM TEMPERATURE

Sunshine during previous day (hr.) ...	0–1·9	2·0–3·9	4·0–5·9	6·0–7·9	≥8
Mean rise in minimum temperature (°F.)	1·9	3·8	4·4	4·7	5·4

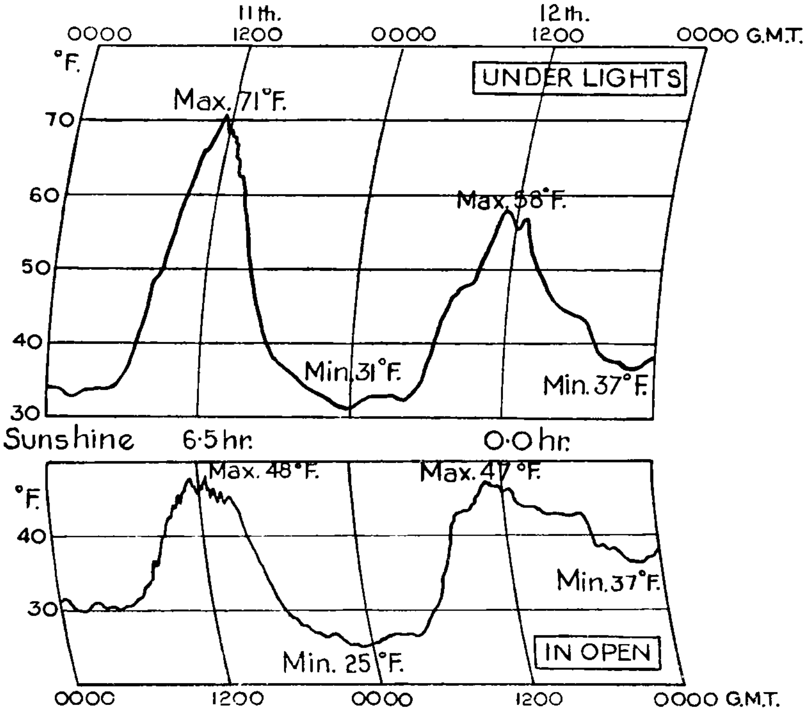

FIG. I—THERMOGRAM OF AIR TEMPERATURES AT 4½ IN. ABOVE BARE SOIL UNDER DUTCH LIGHTS AND IN THE OPEN

Period : March 11–12, 1949

This dependence of the rise in minimum temperature on the number of hours of sunshine in the previous day is well shown in Fig. 1. The difference between the minimum under the frame and the minimum in the open was 6°F. on the morning of March 12 following 6½ hr. sunshine on the 11th, and zero on the following night after a day with no sunshine.

The number of frosts as shown in Table III seems to be reduced by one third in February and two thirds in March, while serious frosts are reduced by three quarters in February and four fifths in March. It is, however, stressed that this protection may not be reached when the frames are cropped.

Rises during April.—The frequency is given in the third line of Table II, the range of difference being from 0° to 10°F. Two frosts were recorded in the open, none in the frames, where the lowest minimum was 38°F.

Again a relationship was apparent between the rise in minima and the sunshine of the previous day. With a sunshine total of 2 hr. or less the mean rise was 3·2°F., with a total of 9 hr. or more, 6·8°F.

Rise in maxima.—No very significant difference was found between the maxima in the 5-light and 2-light frames. This difference was of the order of 1°F. in February and 2–3°F. in the rest of the period, the 2-light frame being the warmer.

The simplest way to summarize the rise in maxima is to construct a table showing the average rise against the total sunshine up to 1300 during the day.

TABLE V—RELATION OF TEMPERATURE RISE TO SUNSHINE DURING THE MORNING

	Mean temperature rise for sunshine up to 1300 of 0–2 hr.	2–4 hr.	4–6 hr.	Over 6 hr.
	degrees Fahrenheit			
February	5·3	7·2	11·4	...
March	12·1	19·1	20·5	22·7
April	15·0	17·5	22·0	37·5
May and June	30·0	35·5	37·8	41·5

The simplest formula which can be devised to calculate the approximate rise in maximum temperature at 4½ in. above bare ground is:—

$$D = 0{\cdot}2n + 2{\cdot}5h$$

where D is the rise in temperature, n the number of days after January 31, and h the total of sunshine hours until 1300.

Examples:—

Date	No. of days since February 1 (n)	Total sunshine before 1300 (h)	Rise in temperature (D) Calculated	Observed
	days	hr.	°F.	°F.
February 19 ...	19	0	3·8	5·0
March 12 ...	40	1·5	11·7	13·5
April 1	60	5·5	25·7	23·5

METEOROLOGICAL OFFICE DISCUSSION

Upper air climatology of the southern hemisphere

The third discussion of the 1950–51 series, on December 11, 1950, dealt with the upper air climatology of the southern hemisphere, and was opened by Mr. L. S. Clarkson who based his statement on recent papers by Loewe and Radok[1,2], Hutchings[3] and Flohn[4].

Cross-sections representing the distribution with latitude and elevation of the summer and winter means of temperature, slope of isobaric surfaces, and the derived geostrophic zonal wind component from the equator to the Antarctic along longitudes 150°E., 170°E. and approximately 10°W. are published in the papers considered. The cross-sections are based on radio-sonde data from Australia, from New Zealand and the islands in the south-west Pacific, and from the 1938–39 voyage of the German ship *Schwabenland.* Antarctic data from Little America[5] and the various Byrd Expeditions are also incorporated.

A comparison of the cross-sections of mean thickness of the 1000–500-mb. layer along these meridians shows that, in contrast to the northern hemisphere, zonal differences are relatively slight and seasonal changes smaller. The southern-hemishere troposphere is appreciably colder in middle and high latitudes in summer, and this is possibly due to the greater cloudiness of the southern hemisphere, with its correspondingly greater reflection of solar radiation and reduced intake of heat.

The mean temperature cross-sections reveal a marked concentration of the temperature gradient, between the equator and the pole in the troposphere, into a narrow zone between approximate latitudes 20°S. and 40°S. in winter, when a region of maximum temperature in the lower stratosphere is apparent near latitude 45°S. In summer this maximum is displaced southwards to the Antarctic, resulting in a complete seasonal reversal of meridional temperature gradient in the stratosphere polewards of middle latitudes.

The 170°E. cross-section indicates that mean maximum temperature above 2 Km. in the troposphere and mean minimum temperature in the tropical stratosphere are each located a little south of the geographical equator, and also that mean temperatures in the lower stratosphere over the equator are higher in July–August than in January–February.

Defined as representing the height of minimum temperature on the mean temperature-height curves, a high-level tropical tropopause is found in low latitudes, and a low-level polar tropopause in high latitudes, with a region of overlap near 35°S. in winter and 45°S. in summer.

A comparison of the height of the tropical tropopause as found along longitude 170°E. in the southern hemisphere with that along the 80°W. meridian in the northern hemisphere[6] reveals that, whereas in the southern hemisphere the mean height is greater in summer than in winter, in the northern hemisphere the reverse is true, and in the equatorial region, where the two cross-sections overlap, they are mutually consistent in indicating a mean tropopause height 2 Km. lower in July–August than in January–February.

Meridional cross-sections showing the distribution of the geostrophic zonal wind component, as deduced from the mean meridional slopes of the isobaric surfaces, indicate in the winter season, a maximum westerly component of over 50 m./sec. at 12 Km. in latitude 25–30°S., in the region of tropopause overlap. A minimum westerly component in the upper troposphere and lower stratosphere is found in mid latitudes, and is related to the similarly located winter maximum-temperature region.

In summer the primary maximum westerly zonal wind component decreases to about 30 m./sec., and is displaced polewards to around latitude 45°S., again lying in the region of overlapping tropopauses. Along the 170°E. meridian a summer secondary jet stream of 25 m./sec. is found occupying the winter position, and a similar secondary maximum is shown in Hess's northern-hemisphere 80°W. cross-section in summer[6]. The secondary is considered to indicate the intermittent re-establishment of winter flow conditions during the summer season. A detailed comparison with Hess's northern hemisphere cross-section shows summer and winter mean jet streams of much the same intensity and height, but approximately 10° nearer the equator in the southern hemisphere.

A diagram representing together the mean temperature-height curves for the summer and winter seasons in the Antarctic and Arctic, and the annual mean curve for the equatorial region clearly shows the relatively cold Antarctic winter stratosphere, with the reversion from a winter temperature lapse rate to a summer temperature inversion, and the lower summer than winter Antarctic tropopause.

The reversal from winter westerly to summer easterly zonal winds in the stratosphere is related to the seasonal rise in the Antarctic stratospheric temperature, which, above 12 Km., is lower in winter and higher in summer than over the equator. Similarly, variations in the intensity of the tropospheric circulation between the seasons and between the hemispheres are also related respectively to the mean seasonal and inter-hemisphere temperature differences over polar regions.

The opener concluded by suggesting the possible occurrence of fairly well marked mass ascent in the Antarctic winter stratosphere, the thermodynamic effects of which would lead to the observed lifting and eventual destruction of the tropopause inversion, and to stratospheric temperatures decreasing with height in this season. The large seasonal fall of temperature in the Antarctic stratosphere would be an indirect result of such ascent[7] which would involve a return flow equatorwards at high levels[8] with mass descent towards the equatorial tropopause, where such descent would account for the observed lower tropopause and warmer stratosphere at this season. Finally, observations from the southern hemisphere are apparently inconsistent with Rossby's theory[9] that the jet stream is produced through the agency of lateral mixing processes, for, according to this theory, the greater the intensity of such departures from zonal flow the nearer the equator should the resulting jet stream be located. However, the southern hemisphere circulation is more nearly zonal than that of the northern hemisphere, and yet its mean jet stream lies nearer the equator in each season.

The Director opened the discussion which followed by welcoming the increasing amount of upper air data which is now becoming available from the southern hemisphere as a result of the extension of the use of radio-sonde apparatus. He referred to the general adoption of the expression " jet stream " in American terminology, but deprecated the use of this phrase in the British Service until its meaning has been more adequately defined.

Mr. H. H. Lamb thought that zonal differences in the circulation of the southern hemisphere are quite appreciable, and, in support, showed maps of average surface pressure for Antarctic regions in which mean troughs and ridges were very apparent, the isobars deviating widely from parallelism with the circles of latitude.

Dr. A. H. R. Goldie said that he had wondered for many years whether V. Bjerknes' idea that sunspots were the ends of a vortex tube in the sun which was mostly zonal in length but became radial at the ends had any application to the earth's atmosphere. It might be that jet streams were produced by the transference downwards of high-level vorticity in some similar manner. He then referred to observations from Heliopolis which show the tropical tropopause at a lower height in summer than in winter, and concluded by noting the great progress made in upper air meteorology in the southern hemisphere in the last ten years.

Miss N. Carruthers doubted whether temperature distribution asymmetric about the equator was characteristic of the southern hemisphere in general, but found some additional evidence partially confirming the relatively colder equatorial stratosphere in December–February. She also referred to the records of a Japanese ocean weather station which confirm the existence of either a low-level polar or a high-level tropical tropopause in these latitudes. Miss Carruthers said that work on the statistics of upper air observations shows that in the northern hemisphere no one meridian may be taken as representative, but in the other hemisphere meridional differences are much less.

Dr. R. C. Sutcliffe said that, over the United Kingdom, a jet stream can usually be found lying in the warm air over every significant front, and indeed most research shows the jet stream is positionally associated with the polar front. If the southern hemisphere westerly zonal wind maximum is similarly related to frontal air-mass discontinuities, then, while he would not be surprised at finding a front occasionally displaced well to the north, yet he would feel dubious about expecting the mean frontal position as near the equator as the mean westerly zonal wind maximum has been found in these papers discussed.

Another speaker said that experiences whilst forecasting at Capetown had suggested that cold fronts could sweep northwards over south Africa and could be traced north of the equator, where their arrival coincided with the development of associated weather phenomena at Accra and Takoradi in west Africa.

Dr. A. G. Forsdyke referred to an occasion when he had flown through a well marked and active cold front as far north as 27°S., and also spoke of cold fronts penetrating equatorwards as far as Sydney and Durban.

Mr. J. G. Galloway pointed out that the radio-sonde observations on which these papers are based were largely obtained during war time, and may become much less frequent. He suggested that a radio-sonde unit might be attached to a " round-the-world " ocean liner with the object of obtaining recordings along a circle of latitude and so investigating meridional upper air differences more directly. He asked whether several jet streams may co-exist over a series of frontal surfaces.

Mr. E. Gold pointed out that the strongest winds in the southern hemisphere do not necessarily occur in the latitude of maximum mean westerly zonal wind component, since this latitude may merely indicate the position of the most persistent westerly flow, whereas elsewhere stronger easterly and westerly winds may alternate, or meridional components may be large.

Mr. E. J. Sumner compared the circulations of the two hemispheres in relation to " blocking action ", and did not think that Loewe and Radok's results for the 150°E. meridian disproved Rossby's theory that the jet stream results from the equalization of vertical vorticity through the agency of large-scale lateral mixing.

Miss Carruthers stated that a statistical treatment of wind observations lends support to Mr. Gold's remarks, in that mean wind speed (as distinct from mean westerly component) is found to decrease towards the equator.

Mr. Clarkson, in reply, stated that a comparison between Flohn's summer meridional cross-section in approximately 10°W. and the corresponding cross-sections along the 170°E. and 150°E. meridians undoubtedly shows that the position and intensity of the mean maximum westerly geostrophic zonal wind component is much the same in each of these longitudes, and that consequently the evidence from these papers definitely supports the contention that southern hemisphere zonal differences, though not entirely negligible, are nevertheless much less than in the northern hemisphere, where, as Miss Carruthers emphasized, no one meridian is generally representative. Differences between mean surface conditions along different longitudes are no doubt much greater than at higher levels, as Mr. Lamb's maps of mean-sea-level isobars suggest.

The evidence for an asymmetrical latitudinal distribution with respect to the geographical equator of mean maximum temperature in the troposphere and of mean minimum temperature in the stratosphere is confined to that obtained by Hutchings for the 170°E. meridian, and the asymmetry does not necessarily apply to all longitudes in the southern hemisphere.

The work of Cressman shows that the development of the jet stream in high latitudes is usually followed by a progressive displacement equatorwards, and that during this period of displacement the jet frequently divides into two streams. The double jet stream is most probably associated with the arctic and polar fronts, but the coincidence of the location of the secondary maximum in the mean westerly zonal wind component in summer with that of the winter maximum seems significant.

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ROYAL AERONAUTICAL SOCIETY AND ROYAL METEOROLOGICAL SOCIETY

Clear-air turbulence

A joint discussion meeting was held at the Institute of Civil Engineers on December 14, 1950, when Dr. G. S. Hislop read his paper: " Clear-air turbulence over Europe."

Dr. Hislop gave a description and the results of the experimental flights made over west European air routes by two Mosquito aircraft of the British European Airways under contract to the Ministry of Supply. The aircraft were based at Cranfield, Bedfordshire, and flights were made to Rome, Lisbon, Stockholm, Iceland and other places. The objects of these experimental flights were as follows:—

(i) To determine the probable frequency and extent of turbulent areas in clear air and the magnitude of the associated gust velocities.
(ii) To determine the causes and characteristics of this turbulence.
(iii) To provide a basis for the forecasting of such turbulence.

Altogether some 92,300 miles of experimental flight were made between the levels of 15,000 and 37,000 ft.

Dr. Hislop displayed several interesting statistics of the occurrence of turbulence on these flights. For example he gave the number of miles an aircraft would have to fly, on the average, before meeting gusts of various magnitudes, and compared his results with similar statistics obtained in America for lower altitudes. He also compared the mean gust spacing in clear air with that in thunderstorm clouds. It appears that small gusts are met more frequently at high than at low altitudes and that the reverse is true of the larger gusts. Large gusts are much more frequent and more closely spaced in thunderstorms than in clear air at high altitude. Though the largest equivalent gust encountered in the B.E.A. flights was 26 ft./sec. equivalent airspeed (British definition), there is reason to believe that gusts of at least 35 ft./sec. do occur over western Europe in clear air.*

Dr. Hislop then went on to consider the meteorological aspects. The lack of warning of this turbulence at high altitude makes it important to be able to forecast it but before this can be done the causes of the turbulence must be discovered and understood. Dr. Hislop thought that the main cause was the breakdown of smooth flow into eddies by large shear of wind in the vertical as envisaged by Richardson[3], though the evidence for this from the B.E.A. data was not conclusive, lack of upper air observations making deductions impossible in many cases. The horizontal gradient of temperature had been tried as a means of deducing shear in the vertical, using geostrophic and thermal wind assumptions, and the three results obtained showed that the method had promise. Dr. Hislop thought that present upper air observations, even over the British Isles where they are comparatively numerous, were too far apart in space and time for a proper analysis of this turbulence as the atmosphere is probably " patchy " and interpolation of observations therefore not justified in many cases.

Dr. Hislop then drew attention to the occurrence of high-altitude turbulence near jet streams. All jet streams encountered were not turbulent but several noteworthy turbulent incidents were associated with jet streams. Dr. Hislop also remarked on the possible associations of turbulence with the tropopause, upper air depressions, thermal instability, wind speed, the polar front and high ground; none of these appears to be a major factor in causing turbulence though they may be important on occasions. He also drew attention to an unpublished report of the United Air Lines[4] which suggests, as Bannon[5] has done, that wind shear in the horizontal is a significant factor. He concluded by advising the aviator of the best means of avoiding high-altitude turbulence and the best course to take if such turbulence has been encountered.

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* Equivalent gusts up to 54 ft./sec. equivalent airspeed have been recorded in thunderstorms over England[1] and up to about 70 ft./sec. over the United States.[2]

The long discussion which followed was mainly aeronautical and not of great interest meteorologically, for only two meteorologists were given an opportunity of speaking. Prof. P. A. Sheppard welcomed the paper as being of great interest to meteorologists. He emphasized the comparatively small volume of air sampled in the observations described and hoped that other investigations would be made in the future. He thought that more sensitive instruments should be used for investigating this turbulence, for a better appreciation of its nature may well lead to a full understanding of its cause. Prof. Sheppard also stressed the possible importance of horizontal shear, suggesting that instability and hence turbulence may result if horizontal shear is anticyclonic and exceeds the value of the Coriolis parameter. Dr. Scorer suggested that fluctuations of the horizontal wind speed resulting from eddies rotating about nearly vertical axes might be the cause of clear-air turbulence but Dr. Hislop in his summing up of the discussion discounted this theory, explaining that such fluctuations could have but small effect on a fast aircraft.

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LETTER TO THE EDITOR

Ablation in the Scottish Highlands

I read with great interest Mr. Champion's report of the results of work done by the Durham University expedition encamped on the high Cairngorms in July 1949, which I hope may be followed by further exploits of this sort. It would be interesting to know whether the data obtained suggest any association of the rate of ablation with the rainfall amounts. Of course if the period included little or no heavy rain, it might be impossible to get any indication. The variation of ablation with temperature which the expedition demonstrated was what one would expect; but the survival of the snow-beds in the Cairngorms through the dry, warm summer of 1947 goes, with other experience of these hills, to suggest that rain, especially warm rain, even in winter, may be a more effective agent for removing snow than spells of warm, dry weather. One wonders what the greatest rates of ablation per day may be in summer or winter and what weather conditions produce them.

H. H. LAMB

November 21, 1950

REVIEWS

Climate in everyday life. By C. E. P. Brooks. 8½in. × 5½in., pp. 314, *Illus.* Ernest Benn, Ltd., 1950. Price: 21*s*., net.

Dr. Brooks has shown remarkable courage in tackling so vast a subject in such a moderately sized volume. As he says in his introduction, " to fulfil this ambitious programme completely would require a large encyclopædia ", but he has nevertheless covered or touched on a great deal of the ground in the course of some three hundred pages. His achievement is a very useful book, and some minor criticisms, which will be suggested later, should by no means be interpreted as serious encroachments on this main conclusion.

As one of his aims, Dr. Brooks hopes to " help enquirers to ask the right questions ", and it is probably among the most important functions of such a book to further understanding between the climatologists and those, with enormously varied interests, who apply climatological data in their own fields. But it may be equally important in two other related senses in a much wider setting: first, as a means of stimulating a greater appreciation of the patient and unremitting work of climatological observers of all types and as a direct encouragement to these observers, some of whom, very often in the past, have had no very clear idea about the great value of their work; secondly, as an indication to the general reader of the virtually unlimited scope of applied climatology in the organization of modern life and the conquest of climate, and of the many possibilities which as yet have been very incompletely realized.

Even to describe the legitimate range of a book with the present title is a difficult task, and there is some evidence, in the Introduction, in the choice and arrangement of chapters, and in numerous seemingly casual but illuminating remarks, that Dr. Brooks has a wider and grander view than he has anywhere explicitly and concisely set down. One may define the end-points: at the beginning, the obvious—no-one " would export fur coats to the equator or refrigerators to Greenland " (p. 12), and no-one would deny that, to a large extent, food, clothing, shelter, in fact all the fundamental needs of man, and many, if not most, of his other needs must be rationally related to climatic conditions; at the opposite limit, the field of speculation—the extent to which climate has determined (and will continue to affect) the rise and fall of civilizations and the energy of nations (references are given by Dr. Brooks to relevant works by Ellsworth Huntington and S. F. Markham), and beyond this to the question of the eventual control of climate. Between these two extremes is an immensely wide field, with connexions reaching out to every aspect of human activity, in which climate is always and everywhere playing some part.

Not the least important feature in many climatological applications is, of course, the quantitative determination of the importance of various factors which, in a qualitative sense, are more or less obvious, or at any rate already known. It is one of the virtues of Dr. Brooks' book that with several of his chapters he provides data, formulæ, and indications of quantitative methods, which he takes some trouble to explain to the general, non-specialist reader. Another virtue, both for the general and the specialist reader, will be found in the list of more than 150 references at the end of the book (most of which are mentioned in the body of the work). In the Preface Dr. Brooks points out that the literature is immense and widely scattered—often in technical journals—and that he cannot hope to have seen more than a small part of it. But the large selection given will in itself be extremely useful to any serious reader who cares to follow up a few of the many clues it contains.

The material given in most chapters forms a very condensed account of the diverse subjects dealt with, and it would be difficult to summarize further under any particular heading. A glance at the section and chapter headings will show, however, something of the approach and treatment, and something of the choice of topics for fuller discussion. The three sections are: " Living with climate ", " Climate as an enemy ", and " The control of climate ". The first section deals with things as they usually are, in some sort of equilibrium, with a discussion of " The economics of climate " (Chapter I), of " The siting and design of houses and factories " (Chapter II), and of the most important climates to be met with in different parts of the world (Chapters III–VII). There are, of course, frequent comments on how man has adapted his activities, in and out of doors, to the climatic conditions. The second section emphasizes the role of climate in aggressive mood, with chapters on " The deterioration of materials " (Chapter VIII), " Atmospheric pollution " (Chapter IX), and " Climatic accidents " (Chapter X). It is of outstanding interest, with regard to the first two of these chapters, that man himself has provided the aggressor with one of his most offensive weapons, and to note how much remains to be done before it can be taken away again through the complete control of man-made pollution. In the third of these chapters the more spectacular and natural forms of the aggression are discussed—typhoons, lightning, and hail, for example—and in any such condensed account, giving the worst cases, the picture formed must be very impressive. But it is certain that, at least in industrial regions, the constant pollution menace, with its effects on materials and health, is more serious than the occasional burst of climatic bad temper with its trail of damage limited to a relatively small area. The third section indicates how man has tried to counter the climatic aggression not merely by passive adaptation (as in the earliest phases of his development) but also (throughout most of his history as man) by an increasingly positive defence (Chapter XI, " Heating, air conditioning, lighting, clothing "), and now, very recently, by tentative attempts to go over to the counter-offensive (Chapter XII, " Altering the weather ").

There are two weaknesses of the book which, it may be hoped, will be corrected in a later edition. First, there are some twenty odd places where there are misprints of some importance, or loosely phrased sentences which it would be advantageous to rewrite. There is an unfortunate concentration of the bulk of these in the first seventy or so pages, which might confuse the general reader or make the specialist rather suspicious. In particular the chart given as Fig. 1 on p. 19, " Types of climate ", though on a very small scale, shows clearly enough that the islands constituting Japan are divided between " Winter frost and snow climate " and " Typhoon and hurricane climate ". On p. 20, Japan is listed under "Cyclonic-temperate climates", while in Chapter V (pp. 130–50) Japan is described under " Sub-tropical climates with summer rainfall ", with the sub-heading " Monsoon climates of Asia ". The truth may be that the climates of Japan are so diverse that some parts of the islands could be justifiably brought under any of these (and perhaps other) headings. But if this is the view which is taken, there should at least be a note to say so.

Secondly, though this may be purely a personal opinion of the reviewer, the book would be improved by the addition of a fourth section containing a single chapter " Miscellaneous ". The general scheme is good, but with a subject so vast, there are applications of importance which will always refuse to be drawn into any logical classification, and it would serve the useful purpose of showing the encyclopædic nature of the material if a small selection of examples could be taken, almost at random, for the reader to fit into his own scheme. Some of these examples may be a little remote from " everyday life " in the strict sense, but no more so than hurricanes, or hailstones " as large as grape-fruit ", which are discussed in Chapter X. For instance, in the sphere of temperature-humidity data alone, the British Climatology Branch of the Meteorological Office received some months ago, within a very short time, inquiries concerned with the conditions affecting the treatment of premature babies, the functioning of cooling-towers, and the storage of paintings in the basement of the National Gallery. While most of us may be equally remote from the first of these and from the "old master" stage, there is again, between the two extremes, an enormous field of applications closely connected with modern life. It would be interesting to see more examples like this, with some additional emphasis perhaps on those connected with medical practice and research, as well as with the machinery and materials side.

A. BLEASDALE

John Constable's Clouds, by K. Badt. $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in., pp. ix + 102. *Illus.* Routledge and Kegan Paul, London, 1950. Price: 12*s.* 6*d.*

This book should appeal more to artists than to meteorologists, dealing as it does with such subjects as the lives and paintings of painters of the early nineteenth century—Constable, Dahl, Blechen and others, the technical problems that confront landscape painters and poets, and the affinity between the artistic conceptions of Constable and Wordsworth.

Meteorological interest rests partly on the fact that the three painters just named were more than usually interested in clouds, and were notably successful in painting them in a realistic manner, and partly on the author's contention that the special cloud paintings done by Constable in 1821 and 1822 were inspired by Luke Howard's scientific paper " On the modifications of clouds ", which appeared in 1820, and that the excellence of those studies, and his subsequent improved pictorial handling of clouds, were largely the result of his knowledge of Howard's classification.

It would be easier to accept the author's contention if Constable's unusual interest in " sky-scapes " had not developed long before 1820, having been fostered in early life by his duties as a windmiller. Moreover, the difficulty with clouds in landscape is how to do justice to the clouds as such and at the same time subordinate them to the requirements of the composition. There is evidence in some of Constable's early compositions that at one time he was unable to overcome this difficulty, his Glebe Farm being reproduced in this book (Plate 6) in illustration. If it is hard to see how a knowledge of Howard's classification could be a major factor in overcoming the comparatively slight difficulty of portraying clouds for their own sake, it must surely be even harder to see how it can be so important in helping to solve the more difficult problems confronting the painter.

Another point worth noting is the frequency with which clouds do not conform strictly to Howard's types, which has given rise to the rather cynical saying that " the clouds we classify are not the clouds we see". Of the three illustrations of Constable's cloud studies, Plates 3–5, all admirable representations of some of the clouds we see, only one (Plate 5) includes clouds that could fairly be described as of Howard type, and that not to such an extent as to make them suitable for inclusion in a cloud atlas. Plate 3 is a delight for the artist but a headache for the cloud classifier. Plate 4 might have been painted on one of the hot still days of 1949, when lawns were brown and cracked, and the weather forecasts hinted at thunder. Even the black and white reproduction conveys wonderfully the feeling of such a day. Such clouds, which have some of the characteristics of altocumulus castellatus, are not uncommon in very hot weather, especially around sunrise, or soon after, but seem to have escaped the attention of cloud classifiers.

E. V. NEWNHAM

HONOURS

The New Year's Honours List, 1951, announced the appointment of Dr. A. H. R. Goldie, Deputy Director (Research) of the Meteorological Office, to be a Commander, Order of the British Empire.

OBITUARY

S. G. Purches and G. W. Walklate.—It is with deep regret that we record the death of two Air Meteorological Observers, Sergeants S. G. Purches and G. W. Walklate, and the fellow members of the crew of the meteorological Halifax aircraft which crashed off Barra Head on its return from a special meteorological reconnaisance flight on December 29, 1950. Both Mr. Purches and Mr. Walklate were Meteorological Assistants prior to their call-up for National Service. On joining the Royal Air Force, they volunteered for duty in meteorological reconnaisance aircraft and completed their training not long before the accident.

Present and former colleagues in the Meteorological Office extend their deepest sympathy to the parents of Mr. Purches and Mr. Walklate in their loss.

WEATHER OF DECEMBER 1950

Mean pressure was above 1020 mb. over an area centred near the Azores and extending north-north-westwards to about latitude 50°N., and also over a considerable proportion of the northern part of the United States westward of the Great Lakes, and in the extreme north of Canada. It was below 1005 mb. off the west coast of Norway and below 1010 mb. over Italy, Sardinia and the French Riviera.

Mean pressure was above normal over most of the north-east Atlantic, east of about 50°W. and over the Greenland Sea, the excess being more than 10 mb. over a large area between Greenland and the Azores. It was 5–8 mb. below normal over central Europe and the central part of the Mediterranean.

In the British Isles the weather was exceptionally cold with frequent snow. As far as can be estimated at present, it was the coldest December in the British Isles as a whole since the severe December of 1890, and in Scotland since 1886. Locally in the south and west of England, however, December 1933 was very slightly colder.

On the 1st a secondary depression moved east across the north of Scotland, while a trough of low pressure moved quickly east over England. In the rear of these disturbances cold air of Arctic origin covered the British Isles. The cold air accompanied by wintry showers reached northern districts during the 1st, but mild weather with rain prevailed on that day in the south. In the following days small secondary disturbances moving south in the very unstable northerly air stream caused widespread snow, heavy in some northern districts, and keen frost. Snow lay to a depth of 20 in. at Dalwhinnie (1,176 ft.), Inverness-shire, 10 in. at Houghall, County Durham, and Cockle Park, Northumberland, and rather more than 6 in. for a time as far south as Shawbury, Shropshire. On the 6th a depression, which had developed over Iceland, moved south-east to the North Sea; the arctic air was cut off, temperature began to rise and rain occurred in most places. On the 7th a deep depression west of Iceland moved north-east, and on the 8th and 9th a secondary depression approached the west of Ireland and turned north-north-east. The weather continued comparatively mild, and rain fell generally on the 9th and 10th. Subsequently the depressions east and north-east of Iceland moved away east and another burst of Arctic air flooded the country. Depressions developed to the north-west of the British Isles in the unstable northerly current and moved south-east. One depression centred south of Iceland early on the 14th moved to south-west England, thence along the English Channel and then turned north-east to the North Sea. Considerable snow fell during this period; it lay to a depth of 14½ in. at Shanklin, Isle of Wight, 12 in. at Weymouth, 11 in. at Ventnor, and 10 in. at Scarborough, Cannington and Poole on the morning of the 15th, and 15 in. at Gorleston and 14 in. at Scarborough on the 16th. Temperature remained at or below 32°F. continuously at a number of stations from the 13th to the 15th inclusive and on the 15th, temperature in the screen fell to −1°F. at Dalwhinnie, 5°F. at Glenlivet and 8°F. at Manchester (Ringway) and Prestwick. The very cold air supply was cut off on the 17th when a depression over Iceland moved a little north-east and an associated trough moved east over the British Isles; widespread snow fell in England and southern Scotland on the 18th and rain occurred in the west and north on the 19th and 20th. Snow was 8 in. deep at Whipsnade on the morning of the 19th and there were drifts up to 5 ft. deep on the 18th and 19th. Subsequently pressure became high over Scandinavia and cold south-easterly winds prevailed in the British Isles. By the 23rd a ridge of high pressure extended south over the country from an anticyclone over Greenland, and light northerly or north-easterly winds, with local slight sleet or snow, prevailed until the 26th, when an anticyclone to the north of Scotland moved to Scandinavia and winds veered to E. Thereafter this sytem moved rather quickly south-west to Scotland and then south; weather continued cold, with slight precipitation. On the 29th and 30th a depression, north-westward of Ireland, moved slowly south-east to the Irish Sea, and on the 30th and 31st a trough of low pressure moved east over England. Snow fell rather widely and was heavy locally in northern England and parts of Wales on the 30th. At 1700 on the 30th snow lay 9 in. deep at Southport, and at 0900 on the 31st it was 6½ in. deep at Lake Vyrnwy and 6 in. at Manchester and Liverpool.

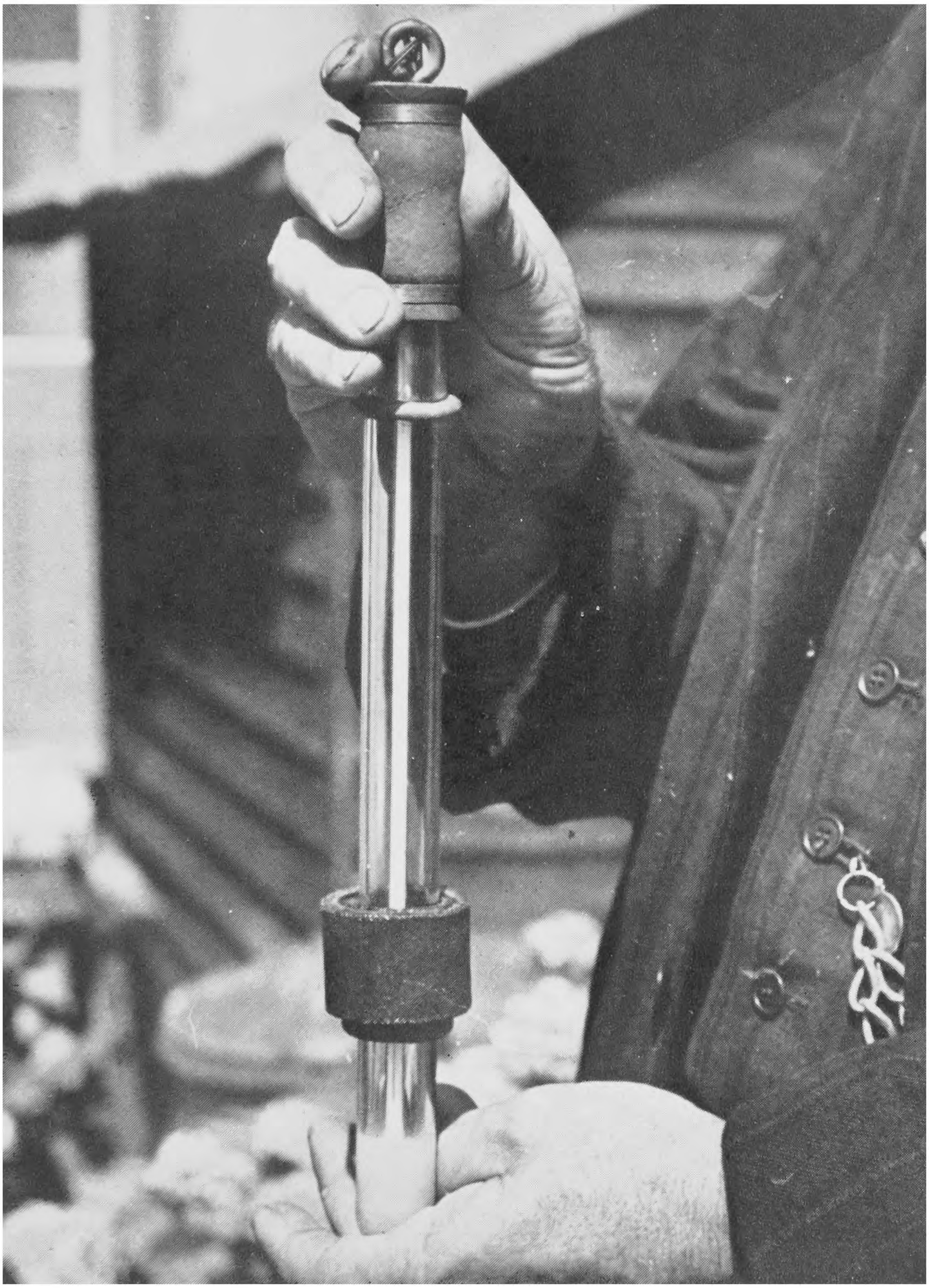
The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	55	6	−5·6	76	−1	102
Scotland	53	−1	−5·5	60	−2	120
Northern Ireland ...	51	13	−5·8	97	0	88

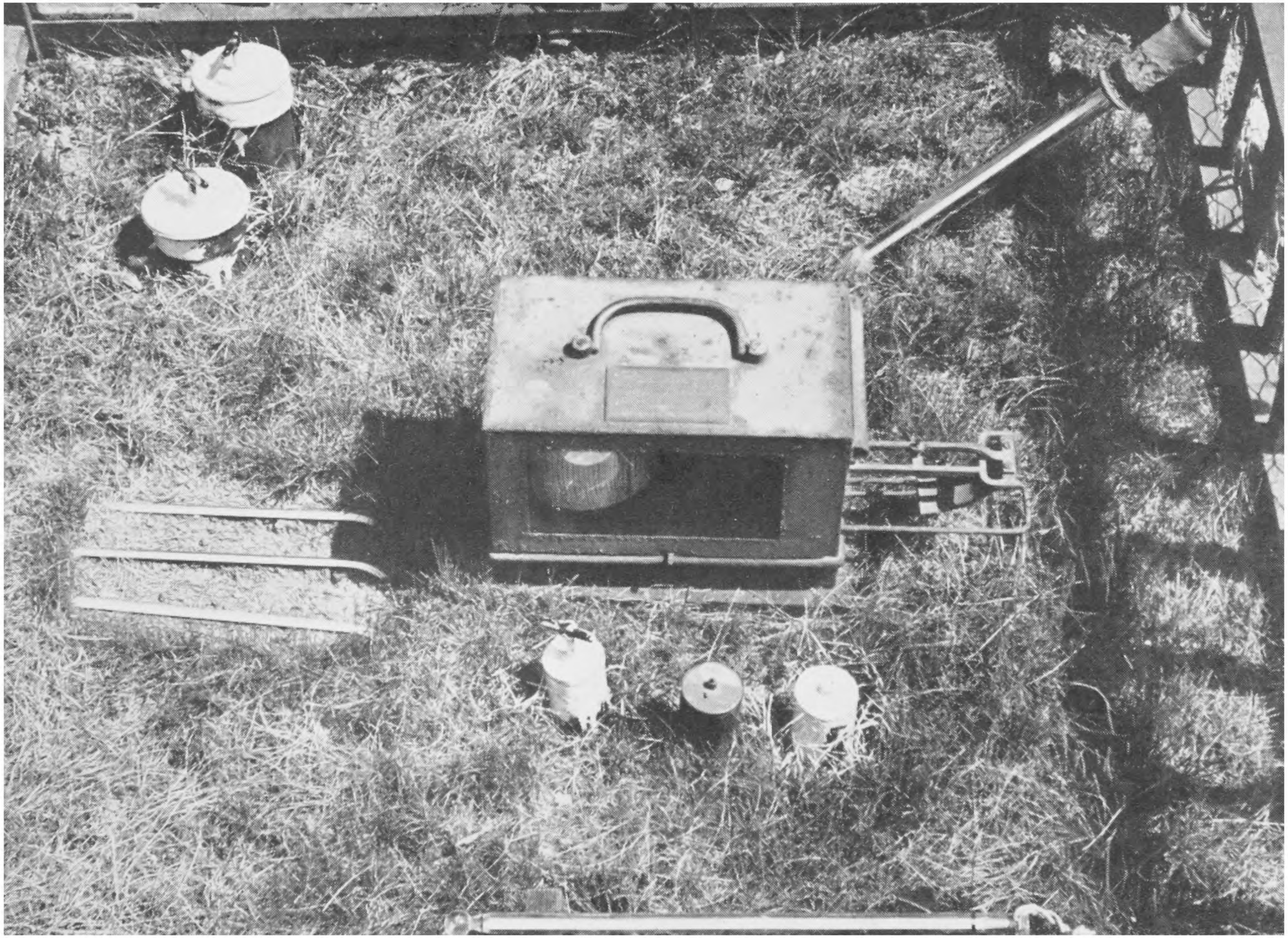
RAINFALL OF DECEMBER 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·61	67	*Glam.*	Cardiff, Penylan ...	2·41	48
Kent	Folkestone, Cherry Gdn.	2·95	92	*Pemb.*	Tenby, The Priory ...	3·92	78
„	Edenbridge, Falconhurst	2·51	76	*Card.*	Aberystwyth	3·16	79
Sussex	Compton, Compton Ho.	2·72	65	*Radnor*	Tyrmynydd	4·52	55
„	Worthing, Beach Ho. Pk.	2·12	70	*Mont.*	Lake Vyrnwy	5·08	72
Hants.	Ventnor, Roy. Nat. Hos.	2·58	78	*Mer.*	Blaenau Festiniog ...	6·06	48
„	Bournemouth	2·24	58	*Carn.*	Llandudno	3·04	105
„	Sherborne St. John ...	1·60	49	*Angl.*	Llanerchymedd ...	4·38	100
Herts.	Royston, Therfield Rec.	1·21	52	*I. Man*	Douglas, Borough Cem.	3·80	77
Bucks.	Slough, Upton... ...	1·79	71	*Wigtown*	Port William, Monreith	2·00	44
Oxford	Oxford, Radcliffe ...	1·30	53	*Dumf.*	Dumfries, Crichton R.I.	1·90	44
N'hants.	Wellingboro', Swanspool	1·43	61	„	Eskdalemuir Obsy. ...	2·50	36
Essex	Shoeburyness	1·67	91	*Roxb.*	Kelso, Floors	1·27	55
„	Dovercourt	1·71	80	*Peebles*	Stobo Castle	2·32	61
Suffolk	Lowestoft Sec. School ...	2·47	106	*Berwick*	Marchmont House ...	1·91	68
„	Bury St. Ed., Westley H.	1·56	65	*E. Loth.*	North Berwick Res. ...	1·48	69
Norfolk	Sandringham Ho. Gdns.	1.86	73	*Midl'n.*	Edinburgh, Blackf'd. H.	1·56	67
Wilts.	Bishops Cannings ...	1·49	45	*Lanark*	Hamilton W. W., T'nhill	1·65	38
Dorset	Creech Grange... ...	3·59	81	*Ayr*	Colmonell, Knockdolian	2·57	46
„	Beaminster, East St. ...	3·34	70	„	Glen Afton, Ayr San ...	2·80	44
Devon	Teignmouth, Den Gdns.	3·59	85	*Bute*	Rothesay, Ardencraig...	2·11	39
„	Cullompton	3·97	90	*Argyll*	Morvern (Drimnin) ...	4·40	56
„	Ilfracombe	4·82	100	„	Poltalloch	1·46	23
„	Okehampton, Uplands	5·06	72	„	Inveraray Castle ...	3·12	31
Cornwall	Bude, School House ...	4·18	96	„	Islay, Eallabus... ...	3·54	60
„	Penzance, Morrab Gdns.	5·82	102	„	Tiree	4·11	79
„	St. Austell	6·68	110	*Kinross*	Loch Leven Sluice ...	1·90	48
„	Scilly, Tresco Abbey ...	4·09	87	*Fife*	Leuchars Airfield ...	1·03	42
Glos.	Cirencester	1·84	55	*Perth*	Loch Dhu	...	...
Salop	Church Stretton ...	2·51	71	„	Crieff, Strathearn Hyd.	1·92	43
„	Shrewsbury, Monksmore	2·01	82	„	Pitlochry, Fincastle ...	2·05	51
Worcs.	Malvern, Free Library	1·80	65	*Angus*	Montrose, Sunnyside ...	1·42	51
Warwick	Birmingham, Edgbaston	1·67	62	*Aberd.*	Braemar	1·84	52
Leics.	Thornton Reservoir ...	1.34	50	„	Dyce, Craibstone ...	2·38	70
Lincs.	Boston, Skirbeck ...	1·34	62	„	Fyvic Castle	1·84	54
„	Skegness, Marine Gdns.	1.10	50	*Moray*	Gordon Castle	3·09	115
Notts.	Mansfield, Carr Bank...	1·61	56	*Nairn*	Nairn, Achareidh ...	1·84	90
Derby	Buxton, Terrace Slopes	4·14	73	*Inverness*	Loch Ness, Garthbeg ...	3·33	72
Ches.	Bidston Observatory ...	3·08	116	„	Glenquoich	6·09	42
Lancs.	Manchester, Whit. Park	3·49	108	„	Fort William, Teviot ...	3·29	31
„	Stonyhurst College ...	3·13	65	„	Skye, Duntuilm ...	2·88	46
„	Squires Gate	2·96	95	*R. & C.*	Tain, Tarlogie House ...	2·00	70
Yorks.	Wakefield, Clarence Pk.	1·36	56	„	Inverbroom, Glackour...	5·61	76
„	Hull, Pearson Park ...	2·61	108	„	Applecross Gardens ...	6·50	101
„	Felixkirk, Mt. St. John	3·07	127	„	Achnashellach	6·48	68
„	York Museum	1·83	82	„	Stornoway Airfield ...	6·63	112
„	Scarborough	4·58	192	*Suth.*	Loch More, Achfary ...	8·04	87
„	Middlesbrough... ...	2·89	149	*Caith.*	Wick Airfield	4·56	148
„	Baldersdale, Hury Res.	1·88	51	*Shetland*	Lerwick Observatory ...	3·27	68
Norl'd.	Newcastle, Leazes Pk....	2·02	86	*Ferm.*	Crom Castle	2·98	72
„	Bellingham, High Green	2·47	68	*Armagh*	Armagh Observatory ...	2·67	85
„	Lilburn Tower Gdns. ...	2·86	109	*Down*	Seaforde	3·04	74
Cumb.	Geltsdale	1·57	41	*Antrim*	Aldergrove Airfield ...	3·91	114
„	Keswick, High Hill ...	2·60	39	„	Ballymena, Harryville...	4·21	95
„	Ravenglass, The Grove	2·62	57	*L'derry*	Garvagh, Moneydig ...	5·28	132
Mon.	Abergavenny, Larchfield	2·13	48	„	Londonderry, Creggan	5·17	118
Glam.	Ystalyfera, Wern House	4·90	59	*Tyrone*	Omagh, Edenfel ...	3·77	89



EARTH THERMOMETER SHOWING THE "COLLAR" TO PREVENT CONVECTION
(see p. 48)



ENCLOSED PATCH OF GRASS FOR EARTH THERMOMETERS AT CUDDINGTON, SURREY

Caps of tubes referred to are painted white (see p. 48).

M.O. 548 AIR MINISTRY

METEOROLOGICAL OFFICE

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ESSAY ON FRONTOGENESIS AND FRONTOLYSIS

By H. H. LAMB, M.A.

Part II. Deformation field and circulations in the vertical plane

Subsidence is generally considered as a frontolytic agency. Frontal lines of discontinuity in the horizontal plane tend to disappear in the accompanying (horizontal) divergence, and clear skies and sunshine favour modification of the shallow layer of cold air in the lowest levels by surface heating.

Nevertheless convergence in the vertical plane will tend to sharpen existing discontinuity (e.g. frontal) surfaces aloft wherever air subsiding from higher levels meets either vertical up-currents or air masses rising at a slanting angle. The same effect will be present where subsiding air descends upon another body of air which is sinking less rapidly, as the air layers next the earth's surface are normally compelled to do in regions of active subsidence. Namias[8] has given diagrammatic illustration of these points (see also Chromow[9]). Conversely, frontal surfaces associated with general upward motion (as at normal, active fronts with horizontal convergence in the lowest layers) tend to weaken and become diffuse aloft.

It is a curious fact that, when horizontal divergence supplied by downward motions in an anticyclonic situation weakens a front on a surface map, subsidence tends to maintain and sharpen the discontinuity surface aloft. The vertical analysis will sometimes show these sharpened discontinuity surfaces maintaining their identity aloft throughout the life of an anticyclone and eventually becoming involved in renewed horizontal convergence and uplift when the anticyclone breaks down. Upgliding cloud sheets of thin stratus, altostratus or cirrostratus, then appearing in the region of general fall of pressure far ahead of any surface fronts, may give rainfall, sometimes well within the decadent anticyclone. Such cloud systems tend to be located at the surviving discontinuity surfaces aloft, themselves beginning to be deformed by the convergence and vertical expansion of the lower air layers.

An example of the maintenance and sharpening of discontinuities aloft in the vertical convergence associated with subsidence may be followed through all stages of the process in Fig. 9, which shows a vertical analysis (time cross-section) of the lower atmosphere over Downham Market, Norfolk, during the life of an anticyclone centred over England between April 17 and 20, 1945. The time cross-section has been given a time scale that reads from right to left so that the motion of winds and frontal surfaces from west to east may be read in normal fashion from left to right across the paper. The anticyclonic centre first

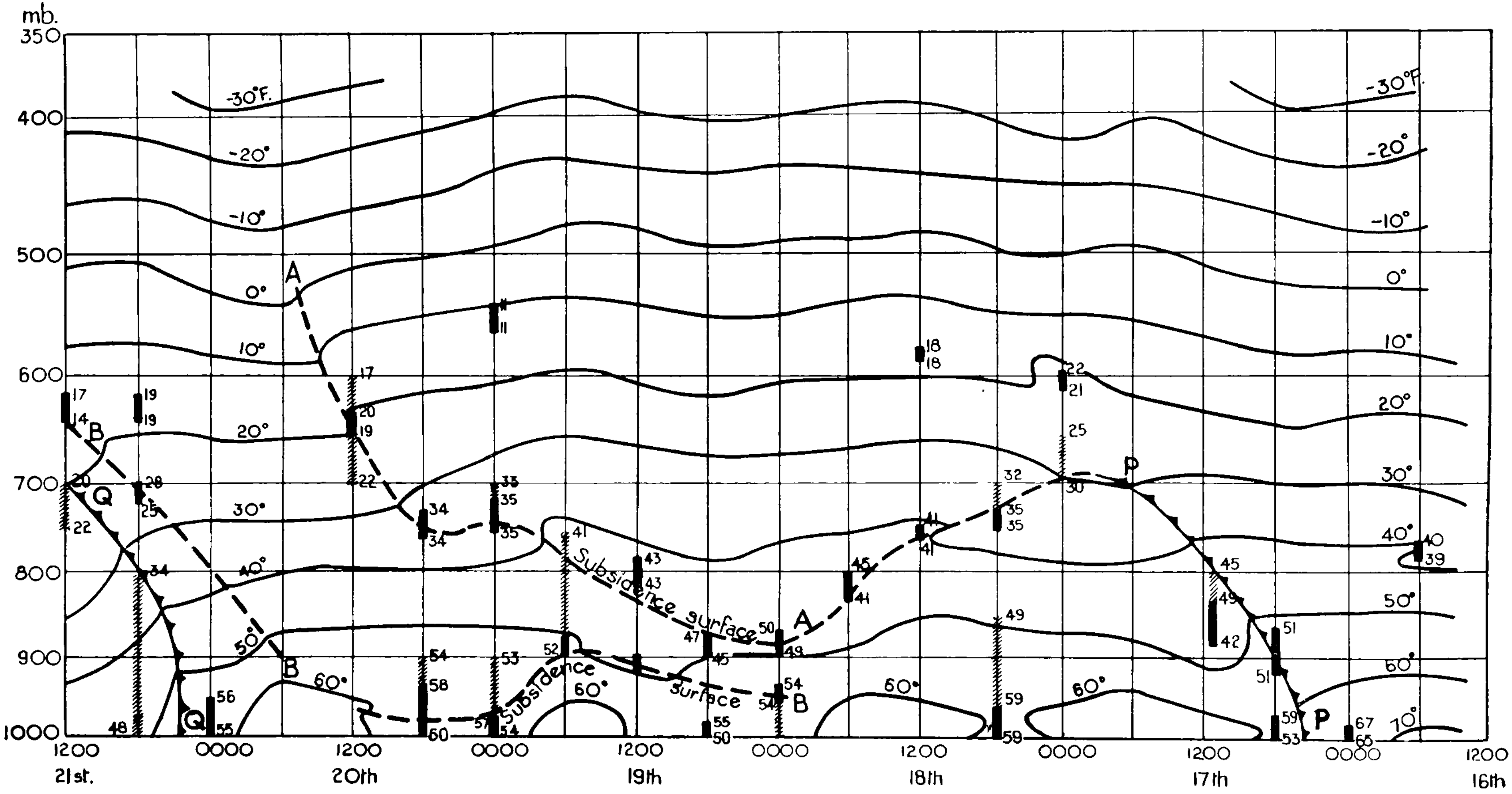

FIG. 9—VERTICAL CROSS-SECTION THROUGH THE ATMOSPHERE OVER DOWNHAM MARKET DURING THE LIFE OF AN ANTICYCLONE, APRIL 16–21, 1945

Vertical lines correspond to successive soundings. Observed temperatures are shown at the top and bottom of stable layers only. Inversions and isothermal layers are marked with thick black lines, stable layers with hatching.

appeared on the 17th in the mouth of the Bristol Channel after the decadent remains of cold front P, which had been well enough marked over Scotland and Ireland the day before, had passed east-south-east. This front was so weak as to be virtually impossible to follow across East Anglia on the surface maps of the 17th. The isotherms on Fig. 9 show it from the temperatures observed on successive soundings between the 950-mb. and 650-mb. levels. It was also shown by a wind shift which was sharpest near the ground, though somewhat blurred by a thermal trough in the isobars ahead of the front on the 16th. Between the 800-mb. and 700-mb. levels the incursion of the colder air mass was shortlived: the temperatures at each level returned in 24 hours or less to the earlier, higher values, rising approximately 3°F. as the frontal surface sank on the 18th and 19th. The frontogenetic sharpening process working on the subsidence surface A, which is the continuation of the cold-front surface P, eventually produced an inversion layer on the 18th–19th where only an isothermal state had existed in the cold-front upgliding stage on the 16th–17th. Temperatures rose 2–4°F. at each height with the downward passage of the subsidence surface and later they fell 3–7°F. when the same sharpened discontinuity surface was lifted again on the 19th–20th. From the 19th onwards subsidence sharpening seems to have made a distinct discontinuity, designated subsidence surface B, out of the top of the ground turbulence layer; and this too can be traced through the uplift phase as the anticyclone collapsed before the advance of the cold front Q from the north-north-west. An interruption of surface B on the afternoon of the 20th is attributed to convective turbulence resulting from the high ground temperatures in the afternoon at Downham Market. Analysis of the aircraft-ascent readings at the neighbouring coastal station of Langham, where less ground heating occurred, shows surface B without interuption. The anticyclone collapsed on the 20th, pressures at East Anglian stations falling about 15 mb. in the 24 hours before the arrival of cold front Q, which is clearly traced in the abrupt temperature falls between the ground and the 700-mb. level on the 21st in Fig. 9. The new air mass brought temperatures 10–20°F. lower than had previously been observed. A very interesting feature of the analysis is the cooling, at various levels aloft, starting 24 hours before cold front Q arrived. At the 700–750-mb. level three stages in the cooling were traced, and at 650 mb. there were two stages in the cooling from 29°F. on the 19th ultimately to 15°F. on the 21st. That this prefrontal cooling aloft was not just a gradual process is seen from the observed inversions and isothermal layers at successively higher levels on successive ascents, most obviously in the case of the subsidence surface A in the ascents of the 19th–20th. The lifting of the subsidence surfaces with cooling of several degrees Fahrenheit in each case explains the successive upper cold fronts often noticed ahead of major cold fronts at the ground, and is attributed to the setting in of renewed horizontal convergence accompanied by vertical expansion (spreading upward) of the lower air layers ahead of the active cold front.

The increase in depth or re-gathering of a preliminary cold air mass ahead of cold front Q, actually considered as the surface air mass which had become shallow in the central regions of the anticyclone during its lifetime, may imply of course considerable horizontal advection. In the case of the English anticyclone analysed in the vertical diagram, Fig. 9, Mr. Douglas finds that the air concerned was drawn north from a cold pool over the Azores in which a deep reservoir of the cold air mass had accumulated, presumably after the passage of cold front P. Similar effects were revealed by an analysis of the anticyclones of the end of March 1946 over the British Isles and indeed appears to be very usual.

The same deduction of sudden stages of cooling in the upper levels ahead of cold front Q on Fig. 9 follows from the appearance of altocumulus castellatus and cirrostratus bands in the previously clear sky ahead of the front on the 20th. These bands of medium and high cloud were orientated parallel to the surface cold front which they preceded, indicating the controlling influence of this front, ahead of which scattered thunderstorms occurred in the Midlands during the evening of the 20th. There was a thunderstorm at Downham Market at midnight, also an hour or two in advance of the front Q. The prefrontal cooling aloft was of course responsible for introducing the latent instability, indicated by the crowding of the isotherms on Fig. 9 on the 20th. The same developing instability in the uplifted layers of air between former subsidence surfaces always favours turbulence in these layers, and this may produce turbulence cloud, whilst upgliding motions at the former subsidence surfaces themselves may lead to the appearance of stratus layers or thin veils of stratiform cloud. This is clearly one way in which the frequently observed multilayered cloud at major cold fronts can develop. Observers on the ground report varying types of altocumulus (C_M types 7, 8 or 9*) according to the number of different layers and the degree of instability apparent in the most unstable of them.

Similar circulation patterns and development of frontogenetic deformation fields in the vertical plane are considered to explain the re-forming of the tropopause, sometimes at a different level from before, after the previously existing tropopause has become diffuse.

Cloud structure at warm and cold fronts.—Bergeron[10,11] has given models of the cloud structure at simple warm and cold fronts and in occluded depressions viewed in vertical cross-section. These models have won general acceptance and have been widely quoted in meteorological literature. Nevertheless observation does not always confirm the standard sequence of cirrus clouds joining with, and giving place to, the medium and then the lower cloud sheets of the lowering frontal surface as one approaches the front, but rather suggests that in very many cases, outside the regions of moderate and heavy rainfall, the cirrus and medium cloud sheets constitute separate systems one above the other and both more or less separate from the lower cloud masses. So far, only one text-book, " Aeronautical meteorology " by G. F. Taylor[12], seems to have drawn attention to this variation. Yet most aviation forecasters nowadays refer in their forecasts to " solid " (i.e. unbroken) cloud masses extending from low to high levels at a frontal surface in particular cases only. It is the practice to search for clear " lanes " or interstices between the upper and lower cloud masses, indicated by stable layers in the upper air soundings, whenever these may be found.

It is clear that refinement of the accepted model of frontal cloud structure is needed in some situations, and that the charting of these clear " lanes " between the upper and lower cloud masses at a front may be of great importance to aviation. We have already made an approach to the problem in relation to the cold front Q in the vertical analysis of Fig.9, which may be taken as an example; and this enabled us to suggest an explanation of the development of multilayered cloud ahead of some cold fronts. The vertical cross-section offers the most promising technique for following the trend of any one stable layer aloft from one sounding to the next, and therefore of correctly diagnosing the course of the clear " lanes " when these exist between cloud layers. This, and the *a priori* likelihood of common occurrence of incomplete stages of frontogenesis and frontolysis, seems to imply that there are in reality few simple warm and cold fronts, and that most pronounced fronts move in association with the decadent remains of older systems.

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*C_M; type 7: double-layered altocumulus usually opaque in parts, a thick layer of altocumulus, or altostratus and altocumulus both present at the same or different levels; type 8: altocumulus castellatus or altocumulus floccus; type 9: altocumulus of a chaotic sky, generally at different levels.

Douglas[13] has given descriptions from early flying experience of some of the more complex cloud structures which occur, perhaps often merely as a result of complicated vertical interchanges of humidity.

Conditions, which however favour deep cloud development at a front and therefore tend to make the upper and lower cloud decks merge into a typical simple system, are:—

(*a*) frontogenetic effects, leading (i) to the supply of fresh warm and humid air for uplift at the frontal surface, and (ii) to increased potential energy available for release as kinetic energy in the upgliding motion;

(*b*) instability in the uplifted air mass, which, in extreme cases, produces altocumulus castellatus as the frontal cloud and causes such turbulence as to destroy minor discontinuities surviving in the higher levels (partial destruction is liable to result in C_M type 9* as the frontal cloud, these chaotic skies being specially common in fronts approaching the British Isles from Spain);

(*c*) high moisture content in the uplifted air mass;

(*d*) moderate or heavy rainfall raising the humidity of the layers it falls through.

In addition, deep cold air masses (or cold pools) bounding the warm sector, resulting in rather steep frontal surfaces proceeding to high levels, also favour the realization of Bergeron's models of frontal cloud structure; although the existence of vestiges of an inner warm sector with additional surfaces of upgliding and duplicate cloud systems is not precluded even here. All such cases involve some unavoidable blind flying for aircraft flying across the fronts, except possibly near ground level. The reverse state of affairs, where frontolytic influences or subsidence are at work, where upgliding is replaced by downward motion, instability replaced by stability and high humidity by low humidity, causes the cloud layers to thin and break and may lead to complete clearance. The nearest cloud layer to the ground and its humidity sources is naturally the one most likely to persist (except in arid regions) and is widely separated by deep layers of clear air from whatever vestiges of thin altocumulus or cirrus may survive at higher discontinuity surfaces above the subsidence zone.

Observers on the ground can corroborate the upper cloud sheets ahead of a cold front encroaching upon a decaying anticyclone in which there has been no low cloud. Banded cirrostratus, ranged parallel with the advancing cold front, sometimes occurs 250 miles ahead. Later, multilayered cloud and rain may appear. On some occasions all the cloud, and more often all the higher

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*See footnote, p. 68.

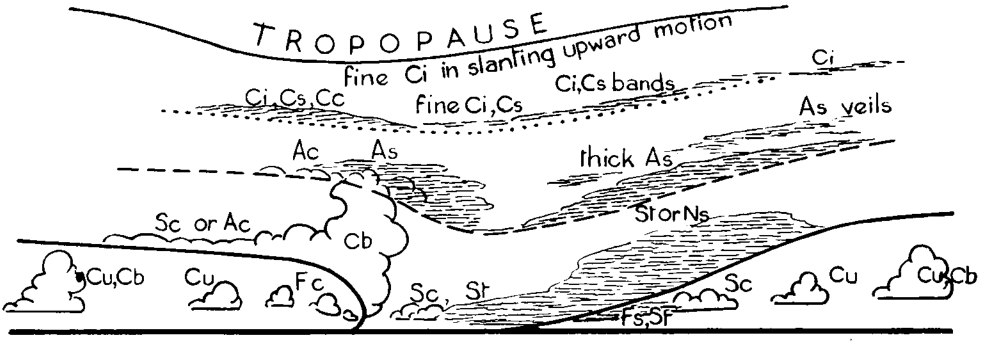
TROPOPAUSE
fine Ci in slanting upward motion
Ci
Ci,Cs,Cc
fine Ci,Cs
Ci,Cs bands
As veils
Ac
As
thick As
St or Ns
Sc or Ac
Cb
Cu,Cb
Cu
Fc
Sc, St
Fs,St
Sc
Cu
Cu,Cb

FIG. 10—SECTION SHOWING CLOUD STRUCTURE OF COMMON TYPE THROUGH A WARM SECTOR

cloud, clears as the front passes, implying that the cloud systems are on these occasions entirely ahead of the front. Fig. 10 gives a common model of frontal cloud structure which fits these observations.

Apart from the main frontal surfaces and the tropopause (both indicated by full lines) two residual discontinuity surfaces (marked by dotted and dashed lines) appear in the model. In origin these residual surfaces, which may be only weakly stable layers when upward motions are general (i.e. under conditions which reduce the main frontal surface to a deep transition layer), belong to older systems which have been imperfectly frontolysed. Inner warm sectors are fairly commonly noticed on the surface maps, and, with careful scrutiny, some traces of such earlier frontal discontinuities might often be discerned.

Such discontinuities are most readily preserved in stable air masses, and are therefore most commonly found as complicating factors in warm air masses' and lifted warm sectors.

Upgliding at weak discontinuity surfaces in the free air produces stratiform cloud, either in thin veils or thicker sheets. Turbulence cloud types may form in the intervening layers, given suitable depth of the layer and lapse-rate and humidity conditions. Inasmuch as the depth of the layers is controlled by the main fronts and associated convergence at the ground, all these cloud systems are liable to show a banded structure parallel to the controlling front. Very fine cirrus or cirrostratus, sometimes only revealed by optical phenomena, may also form just below the tropopause.

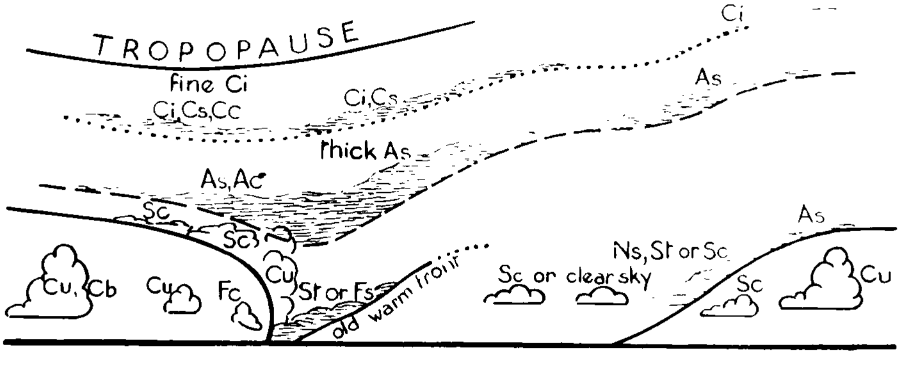
TROPOPAUSE
Ci
fine Ci
Ci,Cs,Cc
Ci,Cs
As
thick As
As,Ac
Sc
Sc
As
Ns,St or Sc
Sc or clear sky
Cu,Cb
Cu
Fc
Cu
St or Fs
old warm front
Sc
Cu

FIG. 11—SECTION SHOWING CLOUD STRUCTURE THROUGH A WARM SECTOR OF MORE COMPLEX ORIGIN

The narrower, inner warm sectors or residual warm tongues aloft are able to give cloud sheets associated with upgliding and turbulence ahead of the cold front, and in the narrowest ones the cloud system may become continuous across the entire warm sector. It is not surprising therefore that cirrostratus and sometimes altostratus are often continuous across narrow warm sectors, and probably across most warm sectors near the tip. The rather loose association of the minor discontinuities at high levels with the main fronts means that a wide range of different positions relative to the latter is possible in different instances; variations occur for instance when a slow-moving cold front is accelerated and the upper cloud sheets shift gradually forward ahead of the front or with changes in the vertical distribution of wind velocities. The number of such separate upper cloud systems also varies.

A slightly different picture is presented by Fig. 11, in which the cold front may be described as a complex front. This arises where the cold front has formerly been an occlusion or is preceded by relics of the warm front of a nearly occluded warm sector having practically the same orientation as the cold front. Surviving traces of occlusion character are reported to be particularly common with cold fronts in Australia; similar cases are however easily noticed at home and elsewhere. In these cases there is a tendency for the warmest and most humid air, occasionally with the only traces of really low cloud in the whole warm sector, to be experienced just before the cold front passes; whereas the simpler case represented by Fig. 10 is liable to show some slight cooling in advance of the cold front.

[*To be continued*

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RELAXATION METHODS AND THEIR APPLICATION TO METEOROLOGICAL PROBLEMS

By F. H. BUSHBY, B.Sc.

Introduction.—During the past fifteen years, R. V. Southwell[1,2] and his associates have developed the " relaxation technique " for obtaining numerical solutions to algebraic and differential equations. The method was originally devised to solve the simultaneous linear algebraic equations which occur in framework problems, but it has now been extended to non-linear partial differential equations of two and three dimensions. The method is a purely numerical one, and the aim is to obtain the answer to a specific problem as quickly as possible. The accuracy which it is worth trying to attain is dependent upon the degree of reliability of the physical data used.

The present article gives a brief indication of the principles involved in relaxation methods, and discusses the type of meteorological problem for which they may be used. The basic principles of relaxation used in the solution of differential equations are similar to those used in solving simultaneous algebraic equations, but the latter can be illustrated more easily and are therefore discussed first.

Algebraic equations.—The solution of three simultaneous linear equations will be considered first

$$P(x,y,z) \equiv a_1x+b_1y+c_1z+d_1 = 0 \qquad \dots (1)$$

$$Q(x,y,z) \equiv a_2x+b_2y+c_2z+d_2 = 0 \qquad \dots (2)$$

$$R(x,y,z) \equiv a_3x+b_3y+c_3z+d_3 = 0 \qquad \dots (3)$$

F_x, F_y and F_z are defined as identically equal to P, Q and R respectively, and are referred to as residuals.

An operations table, Fig. 1, is first constructed in which are placed the increments in F_x, F_y and F_z corresponding to a unit increment in one independent variable when the other two variables are kept constant.

Equations for solution:—

$$F_x \equiv 7x - 2y + 3z - 503 = 0$$

$$F_y \equiv -x + 8y - 6z - 412 = 0$$

$$F_z \equiv -4x - 4y + 9z + 239 = 0$$

Operations Table

Δx	Δy	Δz	ΔF_x	ΔF_y	ΔF_z
1			7	−1	−4
	1		−2	8	−4
		1	3	−6	9
1	1	1	8	1	1

Relaxation Table

Assume solution: $x=0, y=0, z=0$

Δx	Δy	Δz	F_x	F_y	F_z
0	0	0	−503	−412	239
67	67	67	33	−345	306
	43		−53	−1	134
		−15	−98	89	−1
14			0	75	−57
	−9		18	3	−21
		2	24	−9	−3
−3			3	−6	9
		−1	0	0	0
78	101	53			

Solution: $x = 78, y = 101, z = 53$

FIG. 1—SOLUTION OF THREE SIMULTANEOUS LINEAR ALGEBRAIC EQUATIONS

As the equations are linear, if the increment $\Delta F_x = a$ when the increment $\Delta x = 1$, then

$$\Delta F_x = na \text{ when } \Delta x = n \qquad \dots (4)$$

Other similar relationships are also true.

Some initial guess is made at the solution of (1), (2) and (3), say $x = 0$, $y = 0$, $z = 0$. The residuals F_x, F_y and F_z are then calculated, and they are placed in a relaxation table as shown in Fig. 1. The largest residual, say F_x, is then reduced as nearly as possible to zero by making a suitable increment in x. This is known as the basic operation of relaxation. It will, of course, change the values of F_y and F_z. The larger of F_y and F_z is next relaxed in a similar manner, making a suitable increment in y or z. The process is continued until $F_z = F_y = F_z = 0$ when the problem is solved.

The solution should be checked by substitution in the original equation. If a mistake has been made in the relaxation, some of the residuals will not be zero. However, the incorrect solution can now be used as a guess at the correct solution, and relaxation can be recommenced from this stage in the work. It is not necessary to check all the previous working, and this is a great advantage of the relaxation technique.

In problems in which the solution involves decimals, it will not generally be possible to reduce the residuals exactly to zero, but they should be reduced as nearly as possible to zero consistent with the degree of accuracy to which the solution is obtained.

The residuals may only converge slowly to zero, but various processes are available to speed up the relaxation. Block relaxation and over-relaxation are the two most commonly used. Block relaxation consists of making simultaneous equal increments in more than one variable, e.g. $\Delta x = \Delta y = \Delta z = 1$. The effect on the residuals is also indicated in the operations table in Fig. 1. This operation should be used to bring the sum of the residuals to zero, after which normal relaxation will usually give a quick solution. If the reduction of one residual to zero increases the value of the other residuals, over-relaxation will often facilitate the solution. Instead of reducing the largest residual to zero, it is reduced still further to about half its original magnitude but of opposite sign, and this is known as over-relaxation. The degree of over-relaxation is of course arbitrary, but with experience a rough estimation can easily be made.

In a slowly converging problem, it may become obvious that a group of operations is slowly reducing the largest residual, whilst having only a negligible effect on the other residuals. This group of operations can be used together as a group relaxation to reduce one residual to zero and yet produce little change in the other residuals.

In some slowly converging or apparently diverging problems, it may be difficult to bring all the residuals to zero. However it will be possible to find some stage at which F_x, F_y and F_z are in approximately the same ratio, one to another, as they were initially. Using the increments in x, y and z which were necessary to reach this stage, the increments necessary to reduce the residuals approximately to zero can be calculated. This gives an approximate answer to the problem. These values of x, y and z are substituted in the original equations, and new residuals calculated. These will be quite small and can easily be relaxed.

It can be seen from this example how the method can be extended to solve simultaneous linear algebraic equations with any number of variables. Non-linear equations can also be solved, but the relationship (4) does not hold. In practice, the method would never be used for solving simple problems like that in Fig. 1, but it is a very useful method when there are more than 4 or 5 variables.

Differential equations.—A differential equation is said to be solved numerically when the value of the function specified in the differential equation has been obtained at a network of points. The relaxation method can be applied to problems of any order or degree in one, two, or three dimensions, provided that a corresponding approximate algebraic equation can be found relating the values of the function at a network of points separated by small but finite differences (a finite-difference approximation). In two-dimensional problems, a solution is found at nodal points of a regular polygonal net. The net may be triangular, square, or hexagonal, but in practice it is most convenient to use a square net unless the actual boundary is an equilateral triangle or a regular hexagon.

As in algebraic equations, linear equations can be solved most easily, and the relaxation method can be demonstrated by considering Poisson's equation

$$\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} + Z(x,y) = 0 \qquad \ldots (5)$$

In the example a square relaxation net will be used, with nodal points a distance h apart. If the four adjacent nodal points to nodal point O are denoted by A, B, C and D, the finite-difference approximation to equation (5) is as follows:—

$$z_A + z_B + z_C + z_D - 4z_O + h^2 Z_O = 0 \qquad \ldots (6)$$

The error term is of the order of h^4.

The left-hand side of the equation (6) is defined as the residual F_0 at the point O. Similar equations to (6) can be written down for all nodal points inside the boundary which are surrounded by 4 other nodal points. With the boundary conditions, equations similar to (6) give a number of simultaneous linear algebraic equations which can be solved by relaxation methods.

The operations table can therefore be replaced by a diagram such as Fig. 2 showing the relaxation pattern; this being the same for all internal points. The changes in the residuals at O, A, B, C, and D, due to a unit increment in z_0 when (5) is the governing equation, are shown in Fig. 2. Some initial guess at the solution is made, and the residuals at nodal points are calculated.

The residuals are then reduced step by step by adding increments to selected points and making corresponding changes at adjacent points in conformity with the relaxation pattern. A convention is adopted whereby the residuals are written on the right of the nodal point, and increments are written on the left. The working is done in an upwards direction, as is shown in the example in Fig. 4. When the residuals have been completely reduced to zero, the problem has been solved.

Over-relaxation and block relaxation are both very useful in obtaining the solution. Block relaxation consists of imposing equal increments on adjacent nodal points simultaneously. If in a block relaxation a boundary is drawn just outside all points at which a positive unit increment is made, then there is a positive unit increment in the residual at a point immediately outside the boundary for each point inside which is adjacent to it, and there is a negative unit increment in the residual at a point immediately inside the boundary for each point outside which is adjacent to it. Block relaxation should be applied to make the total residual inside the block zero. A simple block relaxation pattern is shown in Fig. 3.

A solution to Laplace's equation

$$\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} = 0 \qquad \ldots (7)$$

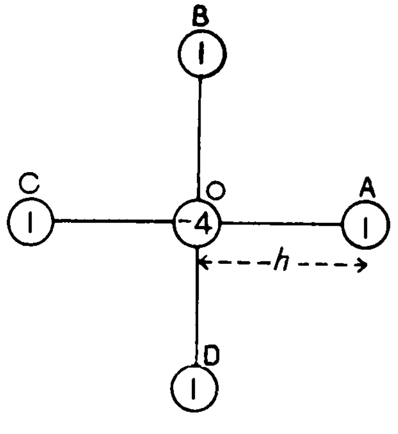

FIG. 2—CHANGES IN RESIDUALS FOR A UNIT INCREMENT IN z_0

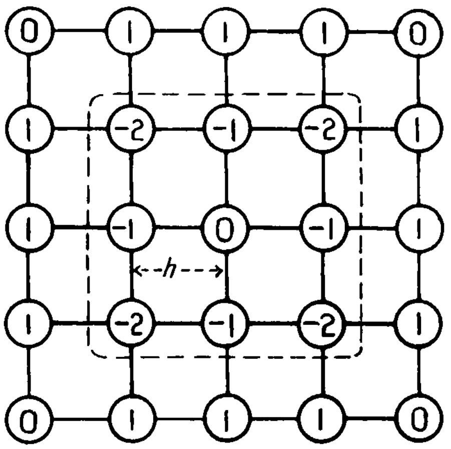

FIG. 3—CHANGES IN RESIDUALS FOR UNIT INCREMENTS AT ALL POINTS INSIDE DOTTED BOUNDARY LINE

is given in Fig. 4. The boundary conditions are given values of w along a square boundary of unit length. A square net of mesh length $\frac{1}{4}$ is used. One block relaxation is made initially to all internal points, and then the problem is completed by the ordinary basic operation of reducing the largest residual to zero.

The boundary may not, of course, always be rectangular; neither may the boundary conditions always be given as boundary values. In these cases, the problem can still be solved by modifications of the method. These are dealt with by Southwell[2].

Appropriate relaxation patterns can be obtained for other two-dimensional partial differential equations. The method can be extended to three dimensions, but care has to be taken over the method of representation. The volume for which the problem is being solved is divided by three systems of parallel planes at right angles. These have to be represented diagrammatically so that

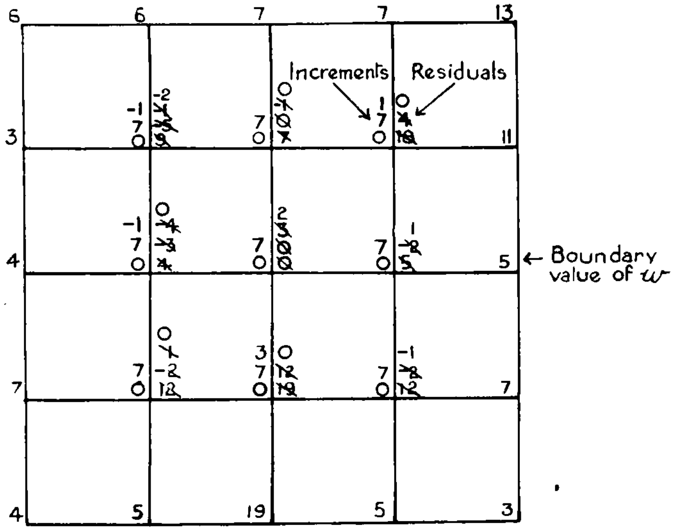

FIG. 4—SOLUTION OF $\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} = 0$

w given along the boundary

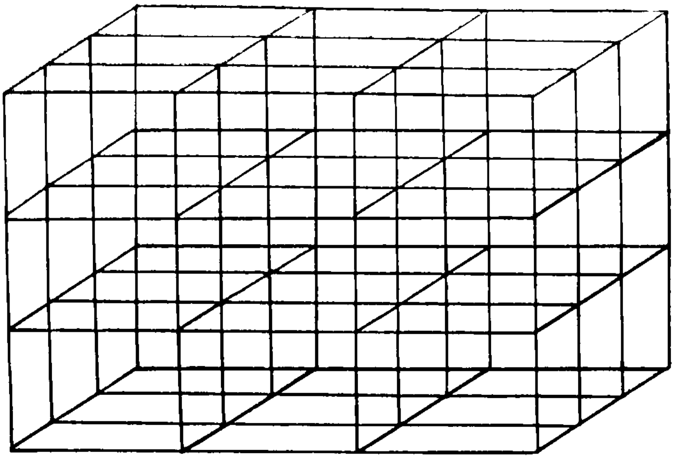

FIG. 5—DIAGRAMMATIC REPRESENTATION OF A CUBIC GRID

the intersections are clearly marked (see Fig.5), and there must also be space to write down the residuals and increments. This can usually be done by extending one dimension.

While the relaxation technique can deal directly with problems in which the boundary conditions are specified equally along all boundaries (sometimes known as " jury " problems[3]) it cannot deal directly with problems in which the boundary conditions are sufficient to determine a unique solution, but are not specified equally along all the boundary (sometimes known as " marching " problems). These latter often occur when one of the variables is a time variable, and this frequently occurs in meteorological problems. Such problems are dealt with by converting the " marching " problem to a " jury " problem. This is done by making a change of dependent variable which will increase the order of the differential equation sufficiently so that the equation could be uniquely solved if the number of boundary conditions on all parts of the boundary was equal to the largest number of boundary conditions given on any part of the boundary. Simple arbitrary boundary conditions involving the new dependent variable can now be added to those parts of the boundary where there are insufficient conditions, without in any way affecting the solution which will be obtained for the original dependent variable. The " marching " problem is thus transferred into a " jury " problem, which can be solved directly by the relaxation technique.

Non-linear equations can also be solved, but these are again more difficult as relations similar to (4) are not true.

Application to meteorological problems.—Charney[4], treating the 500-mb. level as an " equivalent barotropic level " has obtained equation (8) for the instantaneous tendency of the 500-mb. surface when the spherical earth is conformally mapped on a plane by a stereographic projection from the south pole.

$$\nabla^2 \frac{\partial z}{\partial t} = J\,(m^2 l^{-1} g \nabla^2 z + l, z) \qquad \ldots (8)$$

where z = height of 500-mb. contour surface

m = magnification factor $\sec^2\left(\frac{\pi}{4} - \frac{\phi}{2}\right)$

ϕ = latitude

J = plane Jacobian

∇^2 = plane Laplacian

l = Coriolis parameter, $2\omega \sin \phi$.

The right-hand side of equation (8) can be computed numerically for a network of points, and, at a particular time, is a function of position only. Equation (8) is therefore a Poisson equation with the instantaneous tendency as the dependent variable. In equatorial regions there is little change in the 500-mb. contour height, and for boundary conditions $\partial z/\partial t$ can be taken as zero near the equator. The equation can be solved simply by the relaxation technique. Two cases have been investigated in the Forecast Research Division of the Meteorological Office at Dunstable. In each case the solution by the relaxation technique was quite straightforward and simple. The calculated height tendency did not show any close agreement with the change observed over 24 hours, and it is deduced that the fundamental assumptions on which equation (8) is based needs reconsideration.

At Dunstable, relaxation methods have not yet been applied to any further meteorological problems, but further applications are envisaged.

Conclusion.—In this article it has only been possible to deal very briefly with the fundamental principles of relaxation. Convergence of the method is not considered, and indeed no general classical proof of convergence is available. In certain particular cases, however, the method can be shown to converge[1,2]. However, Southwell and his associates have not yet come across a physical or engineering problem in which the solution by the relaxation technique could not be made to converge.

The degree of accuracy of the final solution has not been mentioned, but that again is discussed by Southwell. It is, of course, dependent upon the reliability of the physical data used in the problem.

So far, relaxation methods have only been used in a very limited way in meteorology. In dynamical meteorology the equations of motion of the atmosphere have been formulated in many ways, but, in the past, attempts to demonstrate their validity have been restricted to the consideration of hypothetical ideal depressions for which the distribution of wind and temperature, etc. could be expressed by analytical functions and the solution obtained by analytical methods. However, with the increased information from the free atmosphere there is a great need to work out the consequences of the theoretical equations when applied to the atmosphere as it actually is. This can only be done by numerical methods, and the potential applications of relaxation methods are many. In the immediate future the need is to discover whether the dynamical equations already derived from theory do in fact describe the behaviour of the atmosphere, and if not, to modify them. Ultimately, the application of numerical methods to forecasting may be possible.

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DEVELOPMENT OF MODERN TECHNIQUE IN MARINE METEOROLOGY

By A. H. GORDON, M.S.

The basis of techniques which have been employed during recent years for research in marine meteorology lies in the mechanical sorting and tabulating of marine observations which have been punched on Hollerith cards. Before 1921 all marine data in the Marine Branch of the Meteorological Office had to be extracted by hand from the original ship's logbooks before analysis. The introduction of Hollerith sorting and tabulating machines resulted in an enormous saving of time in the undertaking of any work carried out, and enabled projects such as the preparation and publication of climatological atlases of the oceans to be completed on schedule during the 1939–45 war as required by the Royal Navy.

Hollerith system.—Briefly the Hollerith system may be described as one in which given figures can be represented on a card by holes punched in corresponding positions on the card. The punched cards are inserted in machines in which electrical contact is made through the holes, enabling the cards to be sorted into groups and counted; in addition the columns of figures on the cards can be tabulated and their sum obtained. Three machines play a part in this process, each representing a step in the extraction and computation of marine meteorological data. They are:—

(i) the key punch by means of which the observations are punched on cards

(ii) the sorting machine by means of which the punched cards are sorted into appropriate groupings

(iii) the tabulating machine by means of which the figures on the punched cards are tabulated in columns together with the numerical sum of these figures and the total number of figures in the column.

After the various meteorological elements included in the observations have been punched in appropriate codes on cards, the latter are sorted and filed in packs according to the month and the 10° Marsden Square to which they belong. A total of approximately three and a half million British and six and a half million German cards are held in the Marine Branch at the present time.

The analysis of this vast mass of marine data in a way designed to provide the maximum contribution to meteorological knowledge is a problem which requires the evolution of special techniques. Such techniques have been developed and have been applied to the following three fields of meteorological research: statistical climatology, physical meteorology, and dynamic climatology.

Statistical climatology.—In the past the function of marine meteorology has been limited largely to the preparation of charts and atlases which have contributed to our knowledge of the climatology of the oceans. If a sufficient number of observations can be collected from one place, or from one sufficiently limited area, they will show what is the most frequent type of weather to be expected, or within what limits any meteorological factor may be expected to vary from year to year. Such statistical information may be of considerable value in areas where observations are lacking and for which forecasts cannot be made available with any reasonable degree of confidence; for example, if one requires to know at what time of the year the most favourable weather for a given operation is likely to occur.

There is one important difference between land and marine climatology. On land, except in sparsely inhabited polar or desert regions, a picture of the climatology of the region may be built up from a usually regular series of observations, extending over a period of years, for definite locations. At sea the situation is different. The sources of observation are the ships, and, even on the main shipping routes, the chance of getting many observations from a comparatively small area, say one square mile, is slight. It is therefore necessary to divide up the ocean into appropriate squares of latitude and longitude, usually either 2° or 5°, and to consider that all the observations within any square refer to a point at its centre. In general this method of grouping the observations is not such a disadvantage over the open sea as it would be over land for climate does not change so rapidly with position over the sea. Unlike meteorological observations over land there is little regularity about observations at sea. A series of observations at successive intervals of 3, 4, 6 or even 12 hours may be obtained in a given square, and there may be no further observations in that square for days, weeks or even years. The observations tend to be made mainly along the main shipping routes; elsewhere, over large parts of the ocean, only a few observations are available; these may not give a sample even approximately representing weather conditions for a given square.

One of the most effective methods of displaying climatological information is by means of isopleths of mean values, upper and lower percentile values, and percentage or actual frequencies. The climatological atlases*, which were prepared in the Marine Branch during the 1939–45 war, contained separate charts showing isopleths of the following meteorological elements over the oceans:—

Mean pressure
Percentage frequency of observations of winds of Beaufort force 0–4
Percentage frequency of observations of winds of Beaufort force 7 or more
Percentage frequencies of observations of visibility less than ½ mile
Percentage frequencies of observations of visibility less than 5 miles
Percentage frequencies of observations of snow
Percentage frequencies of observations of precipitation
Percentage frequencies of observations of lightning
Mean cloud amount
Percentage frequencies of observations of cloud amount between nil and 2 tenths inclusive
Percentage frequencies of observations of cloud amount between 3 and 6 tenths inclusive
Percentage frequencies of observations of cloud amount between 7 and 10 tenths inclusive
Mean air temperature
Range of air temperature—difference between upper and lower 5 percentiles

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*Monthly meteorological charts of the western Pacific Ocean. London, 1942, revised 1945, reprinted 1947.
Monthly meteorological charts of the eastern Pacific Ocean. London, 1943, reprinted 1950.
Monthly meteorological charts of the Atlantic Ocean. London, 1944, reprinted 1948.
Monthly meteorological charts of the Indian Ocean. London, 1944, reprinted 1949.

Upper 5 percentile of air temperature
Lower 5 percentile of air temperature
Mean sea temperature
Range of sea temperature—difference between upper and lower 5 percentiles
Upper 5 percentile of sea temperature
Lower 5 percentile of sea temperature
Difference between mean sea and mean air temperature.

The drawing of the isopleths involves considerable smoothing before the pattern produced can be adopted as reasonably representative of actual conditions because of the irregular numerical distribution of the observations and consequent scatter of mean values.

In addition to the isopleths listed above, the climatological charts displayed vector quantities as follows:—

Direction of the vector mean wind by arrows
Isopleths of the force of the vector mean wind
Direction and constancy of predominant winds by arrows
Wind and swell roses.

The climatological charts illustrate very well how the patterns of the various meteorological elements change from month to month throughout the year. They are constructed under the assumption that any long-period variations extending over the whole period covered by the observations are too small to affect the main pattern appreciably.

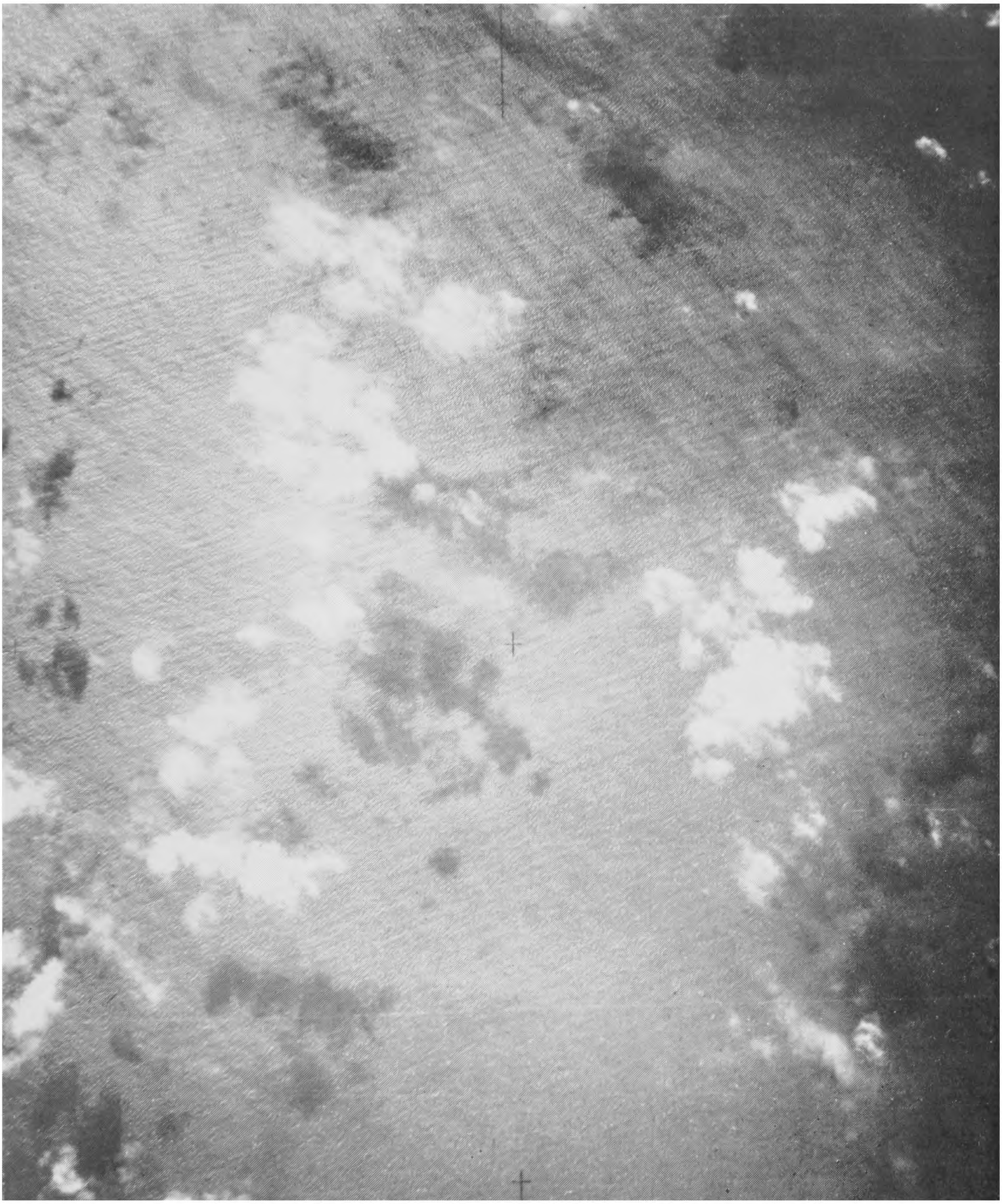
It may be desired to investigate secular changes of the various meteorological elements as, for example, by decades. Marine data extend back for nearly a hundred years so that the sorting of data into decades can be accomplished. The major difficulty lies in the fact that such sorting frequently reduces the number of observations in a given square to such an extent that the mean values or percentage frequencies calculated become meaningless. Statistical significance tests may be applied to the variations of each element, throughout each time interval considered, to test their reality.

However, the application of statistical tests to marine data does not give such reliable results as for other scientific data. Difficulties arise because of the fact that successive ships' observations are not independent of one another.

Physical meteorology.—Climatological charts of the oceans may serve research in certain problems of physical meteorology. For example, the charts showing isopleths of the difference between mean sea and mean air values give one of the variables in the energy equations which describe the heat exchange between the oceans and the atmosphere.

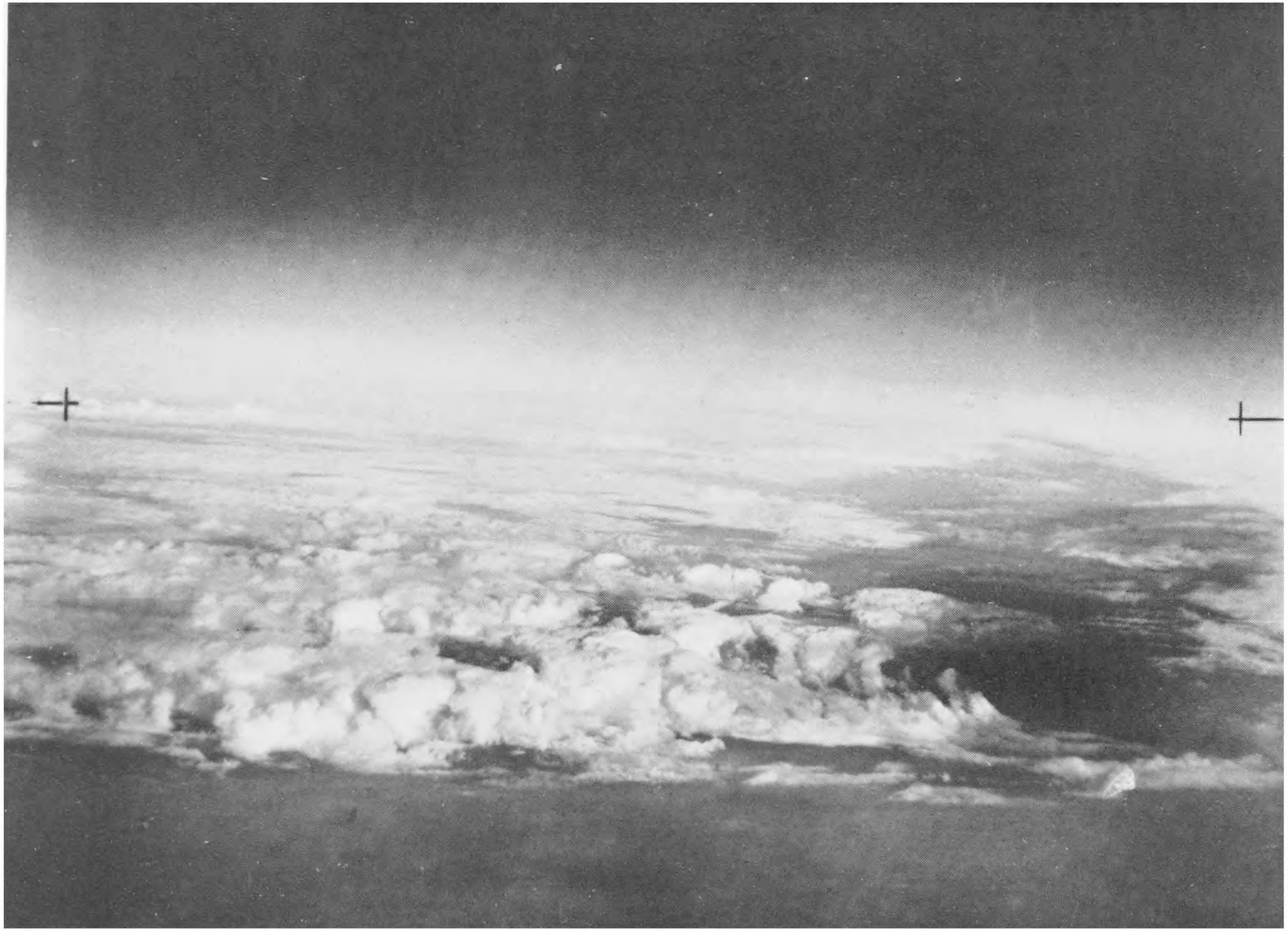
Marine data in selected squares may be sorted into times of day to isolate diurnal variations of the various meteorological elements. Curves may be drawn showing how the mean values vary from hour to hour throughout the day for each month or season as required. Isopleths of the amplitude of the diurnal variation may be drawn on charts to show spatial variations over the oceans.

The isolation of diurnal variation effects can be accomplished best from the analysis of ocean-weather-ship observations. The ocean weather ships are comparable with land stations of the first order in the regularity of their



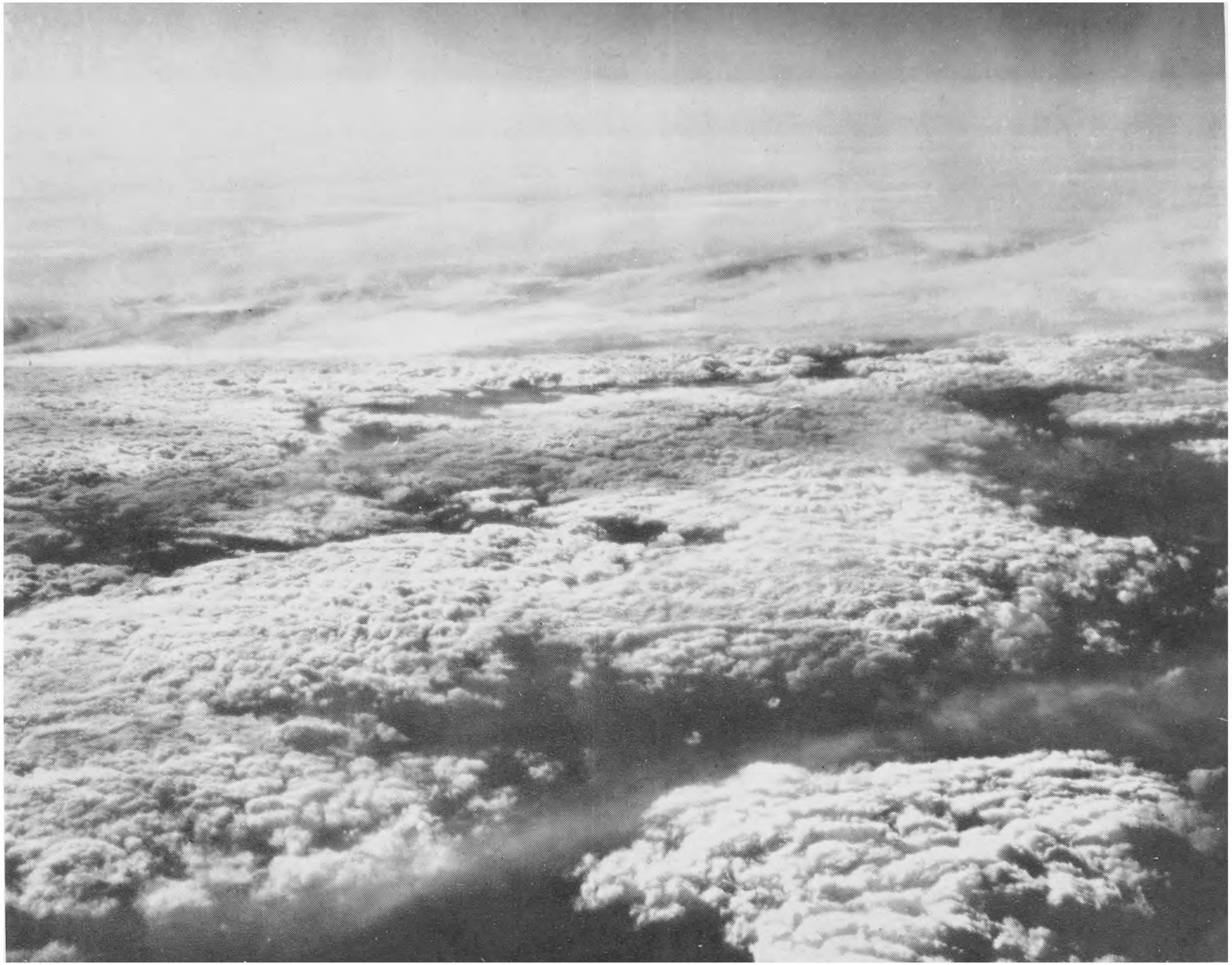
Photograph by R.A.F.

FIG. 1—VERTICAL VIEW OF CUMULUS FROM 32,000 FT. OVER THE BRISTOL CHANNEL IN THE AFTERNOON, FEBRUARY 28, 1950
(see p. 89)



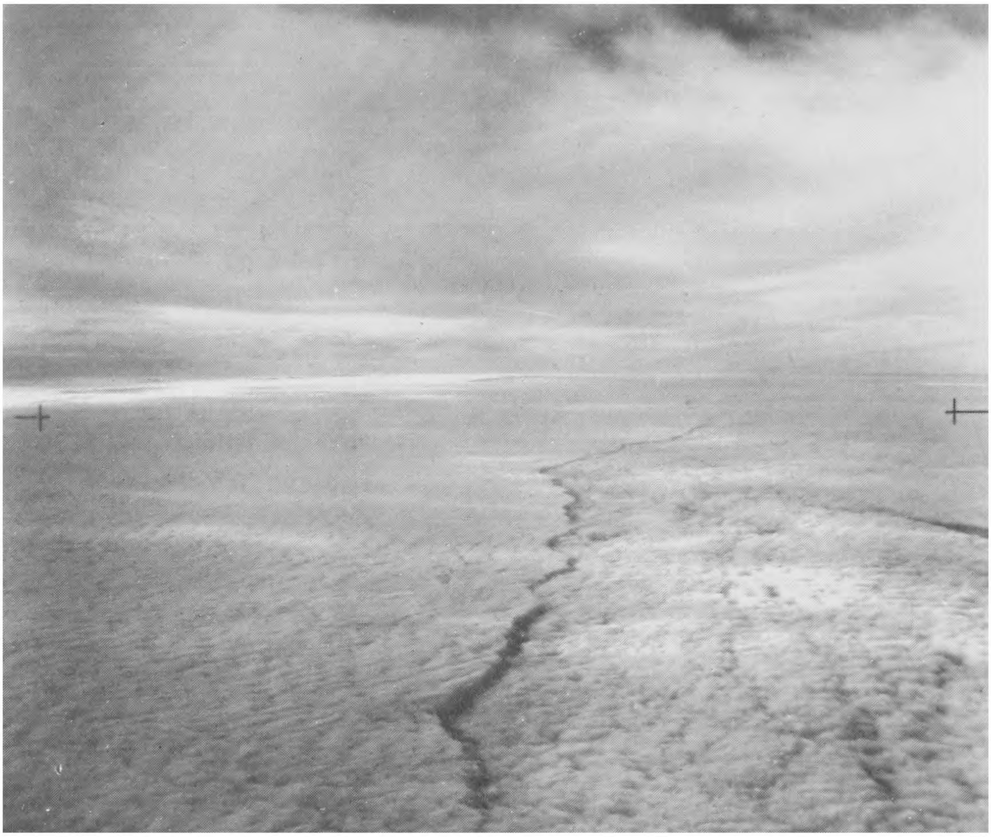
Photograph by R.A.F.

FIG. 2—GENERAL VIEW FROM 40,000 FT. OVER AN UNSTABLE AIR MASS, LOOKING FROM NORTH OXFORDSHIRE IN A NORTH-NORTH-EASTERLY DIRECTION, ABOUT MIDDAY, DECEMBER 8, 1949



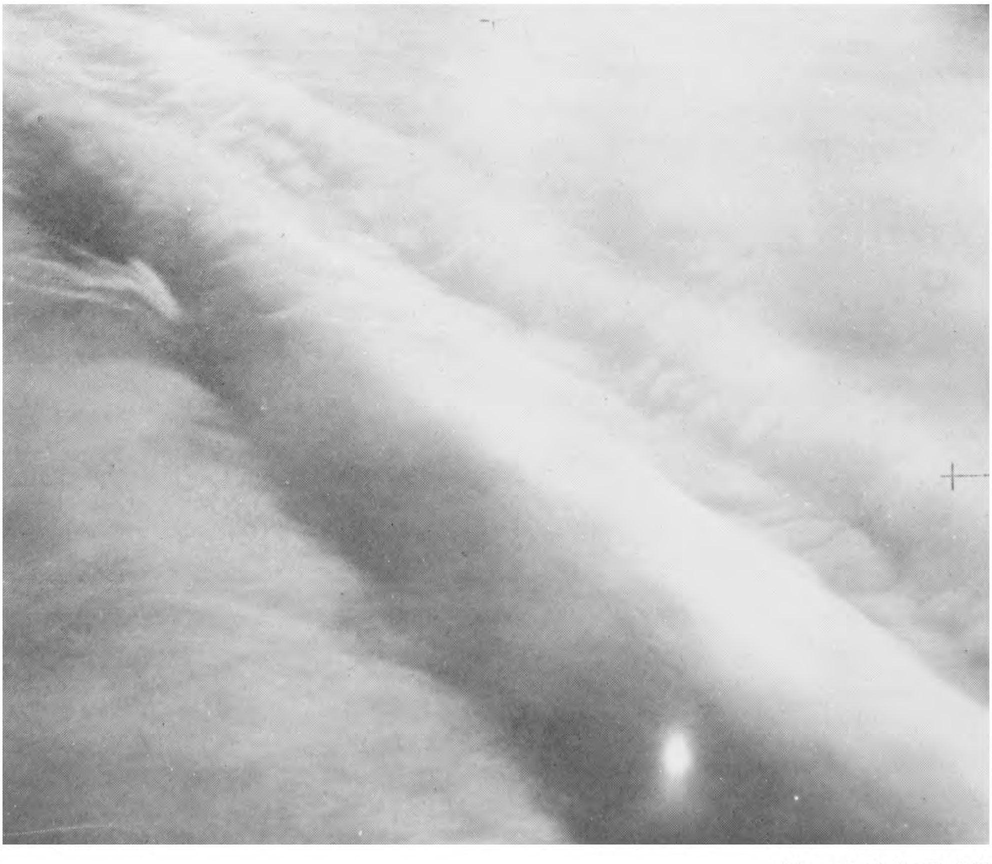
Photograph by R.A.F.

FIG. 3—STRATOCUMULUS AND CIRRUS, FROM 35,000 FT., LOOKING SOUTH OF WEST FROM JUST SOUTH-EAST OF LONDON, MID AFTERNOON, OCTOBER 27, 1950



Photograph by R.A.F.

FIG. 4—ALTOCUMULUS LAYER, FROM 25,000 FT., LOOKING APPROXIMATELY WEST-SOUTH-WEST FROM THE WEST OF LONDON JUST BEFORE NOON, DECEMBER 1, 1949



Photograph by R.A.F.

FIG. 5—CIRRUS FROM 32,000 FT., LOOKING ALMOST DUE SOUTH OVER SALISBURY PLAIN, SOON AFTER NOON, FEBRUARY 28, 1950

observations. They refer to a position which is more or less fixed, and within the past three years sufficient observations have accumulated at these positions for investigations into diurnal variation effects to yield significant results.

In the Marine Branch work has been carried out on the diurnal variation of sea and air temperature, wind velocity and low cloud amount at ocean weather stations. An investigation into the diurnal variation of pressure in the Mediterranean Sea has been completed. The discussion and suggested explanations of these variations are mainly physical in nature.

Work has also been completed on the harmonic analysis of monthly means of sea temperature in the North Atlantic Ocean. The main feature of this work consists of monthly charts of isopleths of the harmonic constants and a discussion of their distribution.

Dynamical climatology.—It may appear difficult to define the line which divides the field of statistical climatology from that of the dynamical climatology. Here, dynamical climatology refers to the study of the application of climatological data to large-scale dynamical problems involving the general circulation of the atmosphere. One of the ways by which the general circulation may be studied is to analyse the seasonal variations of various dynamical properties of the atmosphere, such as pressure, momentum, convergence and vertical velocity, and show how the seasonal variations of these properties change with latitude. The variations may be represented on charts by isopleths of mean values for each month or by isopleths of differences in mean values between succeeding months as, for example, by isallobars in the case of pressure variations. A more concise method of representing seasonal variations of the dynamical properties is to ignore any variations along the parallels of latitude and to consider variations along meridians only. This may be done by the calculation of latitudinal profiles, which are either based on observations extending along one meridian or on the mean of all observations extending along each parallel of latitude between given meridians. Mean variations of the latter kind may also be represented by isopleths on a space-time chart whose axes represents units of months and degrees of latitude respectively.

Current meteorological opinion is tending to break away from the short-term synoptic outlook in an endeavour to solve many of the problems associated with the general circulation of the atmosphere. Instead, techniques are developed based on statistical data extending over periods ranging from several days to many years. Small-scale irregularities in the circulation are thereby ironed out while the dominant features remain.

Marine meteorology has much to offer towards the development of these techniques, and provides unique opportunities for the application of methods of dynamic climatology. Marine data are well suited for the investigation of mean variations of the different meteorological elements and the dynamical properties of the atmosphere, particularly seasonal variations, since weather conditions are less disturbed over the ocean than over land by erratic fluctuations caused by chance topographical and thermodynamical influences.

Several meteorologists have recently used marine data to investigate major problems of the general circulation. C. S. Durst[1] has mapped the seasonal convergence and divergence of mean vector winds over the oceans of the globe in terms of the rate of ascent and descent of air, using the relation between divergence and vertical motion. The isopleths he has drawn, representing the distribution of convergence and subsidence in the surface layers of air, give important information regarding the amount of cloudiness and precipitation which may be expected to occur in regions lacking in regular synoptic observations.

H. Riehl and T. C. Yeh[2] have calculated net meridional wind profiles and net latitudinal divergence and vertical motion profiles in January and July in a study of the intensity of the net meridional circulation. The net latitudinal divergence profiles have been compared with the mean latitudinal sea-level pressure profiles and a mean circulation inferred from the computations. Riehl and Yeh[3] have cast doubt on the validity of the explanation that the descent of air in the trade-wind belt is caused by radiational cooling in the upper troposphere. Instead, they attribute the descent to conditions near the surface and to the removal of vorticity by lateral divergence at the same rate at which it is imported.

C. L. Jordan[4] has calculated latitudinal profiles of mean zonal wind and compared them with profiles of mean geostrophic wind calculated from mean-sea-level pressure observations.

In the Marine Branch calculations have been made of the seasonal fluctuations in the mean latitude of the belts of maximum convergence and divergence and of the axes of the doldrums and semi-permanent subtropical anticyclone in the North Atlantic.

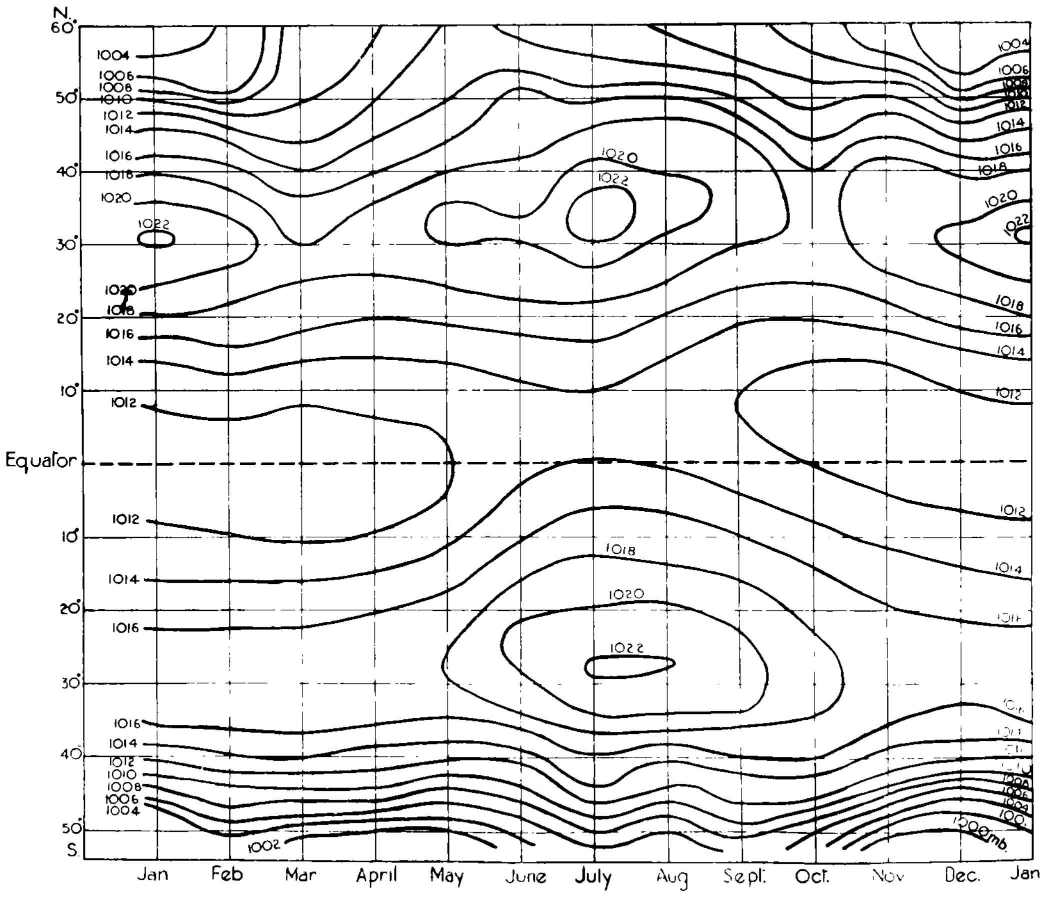


FIG. 1—LATITUDINAL MONTHLY MEAN SURFACE PRESSURE PATTERN OVER THE ATLANTIC OCEAN

Fig. 1 is an example of the kind of information that can be extracted from an analysis of marine data. It shows how the regular seasonal changes in the mean monthly pressure distribution over the Atlantic can be illustrated by a pattern as a function of latitude. Isobars are drawn through pressure values which have been averaged along each two-degree belt of latitude and plotted for each month. Fig. 1 will not be discussed here, but it does provide interesting information about the seasonal behaviour of the atmosphere over the ocean.

The development and application of modern techniques in marine meteorology can lead to a material increase in our knowledge and understanding of the seasonal variations in the intensity and character of the general circulation. The variable which is the primary cause of seasonal variations is known; it is the changing distribution of heat received on the earth's surface as determined by the apparent latitudinal movement of the sun across the sky. Conclusions may then be formulated from a study of seasonal variations regarding the nature of the general circulation itself.

Although purely statistical climatological functions will remain an important feature of marine meteorological work, the time has passed when the sole purpose of marine data is to provide a reference work of mean conditions over the oceans. Modern techniques are now enlisting the vast resources of marine data to assist in the solution of major problems of practical contemporary meteorology in the physical and dynamic fields of the science. It is in this direction that the greatest progress in marine meteorology will be made in the future.

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METEOROLOGICAL OFFICE DISCUSSION

Measurement of upper winds

The discussion held at 11 Carlton House Terrace on January 8, 1951, on the measurement of upper wind was opened by Dr. D. N. Harrison.

Dr. Harrison began by reviewing the assumptions underlying the present methods.

The first assumption is that there exists a " mean " wind at a given level, and that this is the value required for routine synoptic use. Superposed on this mean wind are fluctuations due to turbulence and also those due to errors of observation. A balloon moving with the mean wind velocity would follow a smooth track and the spacing of its positions at equal intervals of time would vary smoothly. The vector displacement of the actual positions from these hypothetical mean positions is random, the distribution depending on the type and degree of turbulence. Displacements of the same type, but differently distributed and of different magnitude, are produced by errors of observation. The plotter cannot distinguish between these two sources of scatter in his trace, and does not need to since he wants to remove both by smoothing.

(Smoothing is a sort of averaging by taking running means over unspecified intervals of time.) It is assumed that if the smoothing could be done correctly we should arrive at the true mean balloon track and mean wind vectors.

The wind vector is measured over a whole number of minutes, usually three. The speed and direction obtained are the actual values at some point which is generally near the centre of the interval, though it may not always be so. These are credited to the standard level occurring somewhere in the middle minute of the three. There is thus the possibility of an error of ±0·5 min. or more in the timing, or ±600 ft. in the height at which the wind is measured.

It is important for the plotter to know over what interval he should aim at taking a mean wind. This involves, in addition to some knowledge of the instrumental errors, a decision as to the thickness of the layer, or the duration of time, over which fluctuations of wind are significant.

Two further points must be remembered:—

(*a*) When the balloon follows a curved track, the straight-line distance between two given positions is shorter than the distance along the track, and therefore the mean speed measured by the vector displacement is too small.

(*b*) As is generally recognized, the wind measurements are not simultaneous values for points vertically above the observing station. The end of the ascent may be an hour after the beginning and fifty miles away.

The errors of radar wind observations can be calculated if the errors of the radar readings are known. The actual magnitudes of the radar errors are not so important as the change between successive readings. In other words, a random error which introduces scatter into the trace is worse than a systematic error which shifts the trace as a whole but has little effect on its shape. In addition to errors in the horizontal plane, height or pressure errors contribute to the wind error, as they lead us to attribute the measured wind to the wrong level. In this case it is the systematic errors which are the more important.

The errors in the angular readings of a radar set on land can be measured by comparison with pilot-balloon theodolite observations. On the ocean weather ships sextant readings provide a standard of comparison for the radar elevation. Alternatively, we can follow the same balloon with two radar sets near together, and from the differences between their readings assess the errors of observation and also the wind errors.

For GL III sets at radio-sonde stations the root-mean-square vector error of a wind measurement over a 3-min. interval is less than 1 kt. at the beginning of an ascent and about 2 kt. at the end. For the ocean weather ships the wind errors are roughly six times as large. In this connexion it is worth noting that on the ocean weather ships appreciable differences have been found between the winds obtained by two computers from the same radar readings. This is due to differences in smoothing the plotted traces.

The normal practice is to take one reading per minute, but it is of interest to consider how much benefit can be obtained from an increase in the frequency. Provided that the displacement of the plotted point from its true position is perfectly random, an increase in the number of readings will lead to an improvement. But if there is a correlation between the displacements—that is, if they are to some degree systematic—then there is correspondingly less improvement to be obtained by an increase in the number of readings. In the extreme case, when the error is constant, a large number of readings is no better than one.

Now if there are fluctuating errors having a certain period, and we take readings at intervals comparable with, or longer than, this period, we shall in general get errors which appear random. But if we take readings at intervals much shorter than the period of the variations, there will be some correlation between the errors of successive readings. This means that an increase in the frequency of reading reduces those errors which are of shorter period than the interval between the readings, but not those of longer period.

The radar-sonde theodolite, which is under development, will include automatic following devices, and electronic computers which will compute the wind components continuously and present mean values over pre-determined intervals. An important question will be the accuracy with which the automatic following mechanism performs its function. There will be errors, and these may be partly periodic. Their effect will depend not only on their magnitude but also on their period. The amount of benefit gained from continuous observation of wind velocity will depend on the nature of the instrumental errors in comparison with the effects of atmospheric turbulence.

Dr. F. E. Jones (Telecommunications Research Establishment), in the subsequent discussion, outlined the new radar-sonde theodolite system. The principal advantages which it is hoped to obtain over existing methods are:—

(i) greater range through the use of an airborne transponder, which gives a signal-to-noise ratio of 5:1 at 100 miles,

(ii) greater detail and accuracy by continuous automatic following and computing.

In the component across the line of sight the high accuracy specified by the Meteorological Office will be difficult to attain at extreme ranges, on account of the low rate of change of azimuth. The characteristics of the automatic-following system will be adjusted to give the best results. A further problem is to reconcile accuracy in the low angular rates at the end of an ascent with ability to follow the high rates which occur at the beginning. The position of the launching point will have to be arranged to minimize this difficulty and to ensure that wind measurement begins as quickly as possible after the release of the balloon.

Dr. F. J. Scrase stressed the importance of being able to distinguish the effects of atmospheric turbulence from those of observational error, and showed a graph of observed rates of ascent up to 100,000 ft. compared with the calculated probable error; this strongly suggested that the observed short-period changes were real. There was a marked decrease both in the mean rate of ascent and in the minute-to-minute fluctuations at the tropopause.

Mr. E. Gold pointed out that the balloon does not follow changes of wind instantaneously, and suggested that the lag might be appreciable.

Mr. D. G. Harley asked whether there were not, in the existing method of measurement, a danger of smoothing out real changes of wind of sufficient magnitude to be significant.

Dr. Harrison replied that plotters ought to be alert to this, and that provision was made for reporting discontinuities. The instructions depended upon the requirements of those who use the observations, and it was hoped that in the present discussion the users would express their views as to what these requirements were.

Dr. R. C. Sutcliffe said that the reason for the lack of a clear reply from the users was that they do not know what is significant. He considered the present standard of accuracy at British stations satisfactory for synoptic purposes. Dr. Sutcliffe also pointed out that with a 100-ft. suspension the swinging of the transponder might introduce an appreciable periodic variation into the measured wind velocity.

Mr. A. G. Matthewman discussed the connexion between the changes of temperature gradient and of wind on a sounding which passed through a front. The changes are related, but do not necessarily coincide. He said that there was a need for more detail in reports.

Mr. H. W. L. Absalom agreed with this.

Mr. J. K. Bannon said he had analysed ascents using measurements over 1-min. intervals, and found that large changes occur, and he made a plea for higher accuracy in wind reports.

Mr. A. L. Maidens said that the practice in regard to smoothing was not systematic, but that, for the 1500 G.M.T. ascents, winds were re-measured over 1-min. intervals without smoothing and the results were available for research purposes.

Several speakers pointed out that the accuracy needed depends on the distance between stations, and that in some regions of the world comparatively inaccurate observations are better than none.

Cdr. J. Hennessy, referring to Dr. Harrison's statement about the errors of the ocean weather ships' observations, said that improvements had recently been made in the type 277 P radar sets on the ships, and further improvements were being planned.

Mr. O. M. Ashford suggested that wind measurements were wanted from a wider area, and that there was a need for a cheap radar-wind set which would be simple to maintain and operate even at the cost of a reduction in range and accuracy.

The Director replied that the peace-time network in the United Kingdom had been planned for research, and the spacing of about 200 miles between stations was roughly equivalent to the interval of 6 hours between ascents. From the research point of view the network was still too coarse. We could not afford to sacrifice range or accuracy, and with the limited amount of effort available it was impossible to develop more than one type of equipment.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on December 20, 1950, Dr. R. C. Sutcliffe, Vice-President, in the Chair, the following papers were read:—

*Batchelor, G. K.—The application of the similarity theory of turbulence to atmospheric diffusion.**

Dr. Batchelor gave a very lucid account of the similarity theory of turbulence. He pointed out that G. I. Taylor had provided, in 1921, a statistical theory of turbulence leading to differential equations which could not be solved. Kolmogorov's similarity theory published in 1941 gave a way out of the difficulty. The similarity theory concerns turbulent motion at high Reynolds numbers. In terms of the older " eddy " conceptions, we may imagine that the original generating mechanism, say a cylinder in a stream or an unstable layer of fluid, gives rise to a set of large eddies of size and directional arrangement dependent on the size and orientation of the generating system. These large eddies produce smaller eddies and so on indefintely. The basic hypothesis is then that the smaller the eddies the more isotropic they become. It is the smallest eddies which finally dissipate the energy as heat. The scheme may also be thought of in terms of the Fourier expression for the velocity in which the non-linear parts of the equations of motion produce, by cross-multiplication, higher and higher order components. From this it follows that the average properties of the small-scale components of any turbulent motion with large Reynolds number are determined solely by the kinematic viscosity and the rate of dissipation of energy. The rest of the theory is dimensional analysis. Dr. Batchelor showed how the theory led to formulæ for the rate of change of the mean square separation of the two particles in turbulent flow. This rate of change is proportional to the time when the particles are so close together that the relative motion is determined by the smallest eddies, and to the square of the time as the particles get further apart. In the discussion, considerable scepticism was shown as to whether the theory had any useful application to meteorological problems.

Quart. J. R. met. Soc., London,* **76, 1950, p. 133.

Mr. Charnock described his analysis of observations of the relative separation of two puffs of smoke which on some occasions supported the theory, but on others apparently did not; but Mr. Davis was not satisfied that Charnock's analysis could strictly be used to test the similarity hypothesis.

Craddock, J. M.—Advective temperature change in the 1000–700-mb. and 700–500-mb. layers.

Mr. Craddock said that his object was to find the extent to which the rate of change of thickness of the 1000–700-mb. and 700–500-mb. layers was determined by advective processes since the advective component of the rate of change could be estimated much more readily from the synoptic charts than the dynamical and non-adiabatic components. The work was done by measuring the advective components for the two layers over Downham Market at six-hourly intervals for the six consecutive winter months October 1945—March 1946, and comparing them with the actual changes in thickness. Statistical analysis gave correlation coefficients of about 0·6 between the thickness tendency and the advective component, and regression equations according to which about half the actual change of thickness is accounted for by advection in the case of the 1000–700-mb. layer and about four tenths for the 700–500-mb. layer. Mr. Craddock recommended that, in the absence of further evidence, the thickness tendency should be taken as half the advective component, and said that further statistical analysis showed that it would be useless to put the thickness tendency equal to the advective component. If the ageostrophic wind is constant with height the advective component is proportional to the area of the polar diagram of the hodograph of wind vectors. Mr. Craddock showed that this use of the hodograph, which has been proposed in the United States, gives poorer results than does the use of the full advective component. Mr. Craddock pointed out that the correlation coefficients showed the actual thickness tendency was the residual of two generally opposite factors, the advective component and the dynamical plus non-adiabatic components. In the course of the discussion. Dr. Eady said his work on instability showed that particles tended to move along a plane about half way between the isentropic surface and the nearly horizontal isobaric surface which might be related to Mr. Craddock's results; Dr. Stagg considered the correlations should be tackled on a basis of synoptic types since it was to some extent known when advection was or was not likely to be predominant; Dr. Sutcliffe said he favoured the investigation of special cases rather than overall statistical analysis, and thought that forecasters could make good estimates of the magnitudes of the components of the thickness tendency in spite of the statistical objections.

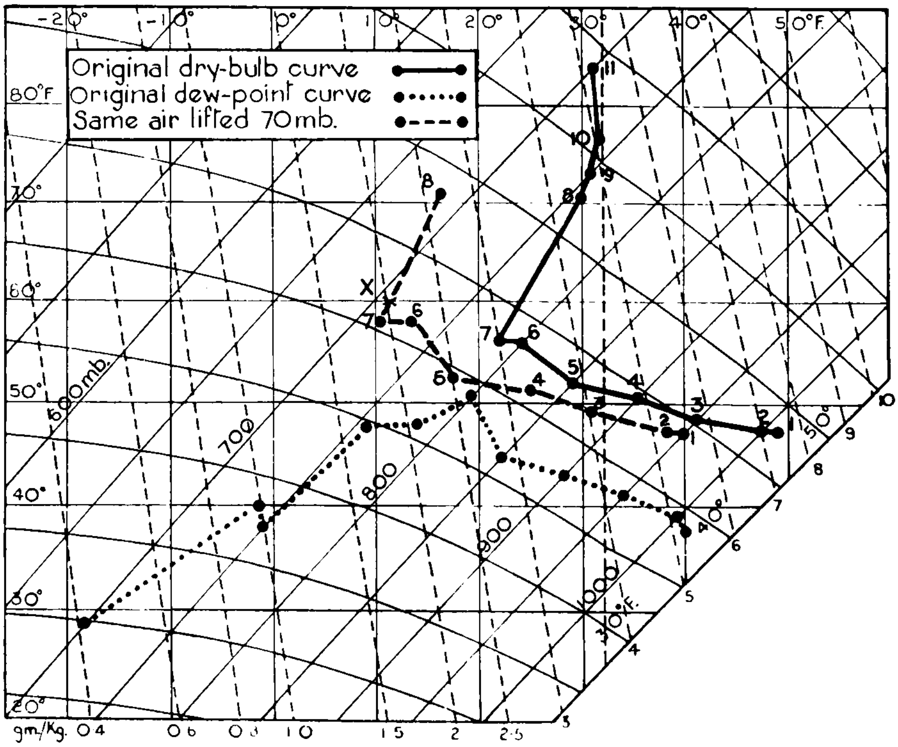
LETTER TO THE EDITOR

Conditional instability over the Highlands of Scotland

On Thursday, October 26, 1950, a southerly air stream covered the whole of Scotland. During the morning no fronts affected Great Britain, and even during the afternoon only the extreme west of Scotland was under the influence of an occlusion in the Atlantic.

The radio-sonde ascent for 1400 G.M.T. was typical of the ascents from Leuchars and Lerwick throughout the day and also from Stornoway as late as 1400 G.M.T.

At first sight these ascents would indicate cloud tops at 5,000–6,000 ft. But, in fact, the top of the cloud over central Scotland was very undulating, though much flatter over the North Sea; and aircraft flying over central Scotland during both the morning and afternoon were in cloud over large areas at 7,000 ft. with light ice and occasional bumps, while occasionally tops rose to 10,000 ft.



TEPHIGRAM OF RADIO-SONDE ASCENT AT LEUCHARS, 1400 G.M.T., OCTOBER 26, 1950

The reason for this increase in cloud tops may be seen from the broken-line curve in the tephigram, obtained by lifting the air represented by the Leuchars ascent by 70 mb., which corresponds to about 2,000 ft., the average height of the Scottish Highlands. The new curve represents air saturated up to the level marked X, and thus unstable to nearly 700 mb., or nearly 10,000 ft.

The choice of 70 mb. is arbitrary, and there is no evidence to show that the upper layers have been lifted to the same extent as the lower layers. If the upper layers were lifted less, the resultant curve would lie between the full curve and the broken-line curve, with the corresponding alteration in the height of the cloud tops.

The effect of ascent of air on the lapse rate is dealt with in text-books*: this is an example of the significance of this principle over the British Isles.

S. E. VIRGO

Pitreavie Castle, Dunfermline, Fife, October 27, 1950

NOTES AND NEWS

High-level cloud photographs

The cloud photographs reproduced in the centre of this number of the Magazine were taken by Royal Air Force aircraft flying over southern England.

The meteorological features revealed by the photographs are discussed in the notes which follow.

Fig. 1, a vertical view of cumulus from 32,000 ft., was taken over the waters of the Bristol Channel in the afternoon of February 28, 1950. The shadows of the cloud on the sea can be identified fairly readily, and it is, in fact, possible to assess the height of the cloud from the length of the shadows—in this case about 3,000 ft. above sea level. It will be noticed that the amount of cloud in the photograph is not large, but that shadows are visible at the top of the print of several clouds which are themselves out of the view of the camera.

Fig. 2 was taken from over 40,000 ft. and shows a general view over an unstable air mass. It was taken on December 8, 1949 at about midday, looking from north Oxfordshire in a north-north-easterly direction. The tops of the cumulus are at 10,000 ft. or rather more. The foreground cloud is some 20 miles from the camera, and, in the middle distance, the cumulus can be seen giving way to layer cloud (mainly altocumulus), though in the extreme distance to the north can be seen further big cumulus with tops to 10,000–15,000 ft. The nearer cloud is spreading out somewhat at the top, showing that convection was limited in height. The pilot stated that the photograph was taken near to a sheet of medium and high cloud (to the south) which was probably the trailing edge of frontal cloud, as an occlusion had just crossed the south-east coast of England that day. It probably accounts for the clear gap in the foreground of the photograph, as convection was not effective until some distance into the cold air. The polar maritime air mass was not unduly unstable, and only about a third of the stations in the Midlands area reported showers during the day. The hazy nature of the horizon will be noted; this is probably due to the haze extending to the tropopause, several thousand feet below the aircraft.

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*BRUNT, D.; Physical and dynamical meteorology. Cambridge 2nd edn., 1941, p. 44.

Fig. 3 was taken on October 27, 1950 from 35,000 ft. from just south-east of London, looking south of west. It was taken in mid afternoon, and the glare of the sun into the camera will be seen on the left-hand side of the photograph. The cloud in the foreground is stratocumulus with tops to about 4,000 ft. together with an isolated line of very thin cirrus. The stratocumulus sheet is seen stretching away in the distance until it is obscured by the main body of the cirrus, visible in the upper part of the print. This cirrus, which is about 20 miles distant, is fibrous in character, but with a clear shadow on the low cloud below; the broken nature of the nearer parts of this cirrus will be realized from the sunlit stratocumulus cloud beyond the shadow. The cirrus becomes more stratified as it disappears into the distance, though there are isolated clouds seen in the middle distance which, the pilot stated, still retained their brightness and character when he flew nearer to them. He did not descend through the cirrus layer, which he reported at about 22,000 ft., but at least in the vicinity of the brighter patches of cloud (nearly 50 miles away) the sheet was thin enough for the lower cloud to be seen through it at times. There was an occluded front from south Wales to the Channel Islands which was almost stationary (it hardly changed position during 24 hours) and sporadic rain was falling from the front well to the west of the area of photography—probably under the most distant cloud. Slight snow was reported from isolated, higher-level stations on Salisbury Plain. The wind at cirrus level was from NW. along the leading edge of the cirrus cloud.

Fig. 4 shows an altocumulus layer taken from a height of approximately 25,000 ft. just before noon on December 1, 1949, looking approximately west-south-west, so that the sun is shining from left to right across the picture. The main interest in the photograph lies in the fault running from the foreground away from the aircraft. The pilot of the aircraft stated afterwards that the cloud top was at a height of about 12,000 ft. above sea level and that the fault between the two sheets appeared to be about 500 ft. deep. Unfortunately, no information is available regarding the possibility of a wind shear at the discontinuity. A somewhat similar fault with a marked shear was described by Frith in *Nature**; on this occasion wind shear was undoubted, as an ice-seeded hole in the cloud across the fault was sheared by the movement of the air at different speeds on the two sides. The only evidence of discontinuity between the two sides of the fault line in the photograph lies in the smoother surface of the cloud to the south compared with that to the north. Above the aircraft, at a height of approximately 30,000 ft. a cirrostratus layer will be seen; there is some evidence of wispy cirrus in the right foreground. It will be seen that this layer is by no means continuous, as the rays of the sun are playing on many parts of the altocumulus layer. The synoptic situation at 1200 G.M.T. on December 1, 1949, was, briefly, a deep depression north-west of the Faeroes moving slowly north-east, and an associated feeble warm front along the English Channel drifting slowly southwards. The photograph was taken from just west of London.

Fig. 5 was taken from an aircraft flying at 32,000 ft. on February 28, 1950, looking almost due south over Salisbury Plain. The cloud seen is cirrus and the long rollers across the photograph were along the line of the upper winds which were from north-west. Close inspection shows that the cloud running diagonally across the photograph is indeed rolling, as upward movement is apparent on its further side and downward, evidenced by the darker line of clearance, on the nearer side. In fact, there was little or no cloud below the cirrus, and the bright spot visible in the centre foreground is probably reflection of the sun from some lake or river surface. The right-hand side of the cloud in the left foreground is showing signs of rising, as the feather of wispy cirrus in the middle distance shows. These clouds were about 20,000 ft. above sea level. The synoptic situation was that of a double occlusion, almost stationary, over west England and Wales, associated with a secondary depression which had moved from the south of Ireland to just south of Cornwall by midday. The fronts were degenerating, but considerable rainfall was still being experienced in Devon and Cornwall (well to the west of the cloud surface shown here). The photograph was taken soon after noon, as the reflection from the water surface and the illumination at the top of the print shows.

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*FRITH, R.; Details of wind structure revealed by artificial nucleation of supercooled clouds. *Nature, London*, **165**, 1950, p. 899.

G. W. HURST

REVIEW

Handwörterbuch der Meteorologie. Edited by Karl Keil. 8¼ in. × 5¼ in., pp. viii + 604, *Illus*. Verlag Fritz Knapp, Frankfurt am Main, 1950. *D.M.* 28.00.

Dr. Keil, of the Meteorological Service of the United States Zone of Germany, has produced a very useful addition to the small number of " encyclopædias " of meteorology and its applications.

Like the " Meteorological Glossary ", Dr. Keil's book provides a substantial descriptive account for the majority of the words included. The article on " clouds " runs to about 1,200 words but the great majority have between 50 and 100.

The book is very up-to-date as is shown by the entries for " ageostrophic ", " okta ", " sublimation nucleus ", Dr. Curry's bioclimatic factor " aran ", the methods of construction and application of charts of the topography of isobaric surfaces, and the synoptic code introduced in 1949. "Jet stream " (called *Strahlstrom* in German as a rule) is, however, neither mentioned as a name on its own account nor, so far as could be seen, is it referred to in any of the articles.

According to the preface the book contains explanations of 3,500 words. No branch of meteorology fails to receive reasonably sufficient description, though it will always be possible with this class of book to think of some words omitted and apparently as worthy of inclusion as some included. The only words noted as omitted as a class are those for the post-glacial climatic periods, Boreal, Atlantic, etc. The book follows the United States " Weather Glossary " in giving explanations of the synoptic-code abreviations, T_gT_g, etc.

An unusual feature is the inclusion of brief biographical details of some meteorologists, though one must wonder at a method of compilation which provides for the omission of Sir David Brunt when Sir Edward Appleton is included.

The only serious errors noted are the definition of the knot as one English mile per hour with English mile clearly stated elsewhere as 5,280 ft., and the incompleteness of the formula (under " Earth ") for the variation of gravity with latitude and height. The " English (London) mile ", equivalent to 1·524 Km., which is almost exactly 5,000 ft., included in the list of " miles ", is new to the reviewer.

A large number of local wind names are included but helm wind is not among them.

The reviewer has little complaint on the whole regarding omissions or errors, and his main criticism of the book is that many unnecessary words are included and that there is some duplication of information between the entries under main subjects and those under parts of them. On the first point, we find many astronomical and physical words such as " aberration " and " neutrino " of no particular meteorological interest; and is it necessary in this glossary to define " Christmas " and explain how the date of Easter is determined? As examples of the second point, the entry for " decrease of temperature with height " is largely repeated under " temperature " and " temperature gradient "; the same comment applies to the entries for " weather service " and " organization of the weather service ". Further, is the entry " London fog " justifiable on the basis of its use as a phrase for dense fog in general? Space saved by judicious pruning could have been used to avoid the rather ugly practice of using in the descriptions only the initial letter of the word described and possibly to reduce the very high cost.

There are no photographs and the only illustrations are small line blocks. The book is well bound. The price of 28 *D.M.*, equivalent to some £2. 3*s*. 0*d*., is very high, especially when compared with 8*s*. 6*d*., the price of the " Meteorological Glossary ".

G. A. BULL

METEOROLOGICAL OFFICE NEWS

Festival of Britain 1951.—Meteorology will have a prominent place among the Festival of Britain exhibits in the Dome of Discovery where British achievements in science will be displayed. The meteorological exhibit will include the making of observations both at the surface and in the upper air, the instrumental equipment which is used, the organization for the collection and dissemination of basic data, the processing of this raw material and the supply of meteorological information to the community generally and in particular to the many and varied interests served by the state meteorological service.

The central feature of the exhibit will be a " live " forecast unit. This unit will be connected to the Central Forecasting Office on the first and second teleprinter channels and by telephone, and will prepare daily, in view of the public, a sequence of synoptic charts. A forecaster will be on duty to answer inquiries, and, by arrangement with His Majesty's Stationery Office, a souvenir *Daily Weather Report* will be prepared for sale at a moderate charge. There will be a meteorological enclosure in the Festival grounds and observations will be made and exhibited daily.

R.A.F.V.R. Meteorological Section.—Meteorologists, whose full time service with the Meteorological Office ended with the war but who have since joined the Royal Air Force Volunteer Reserve, have had to begin by bringing their meteorological knowledge up to date. Most of the reservists have now done this, and in 1951 will be expected to help the work of the Office by attachment to R.A.F. summer camps and to operational squadrons during exercises. A special course at the Meteorological Office Training School is being arranged this year for a small number of reservists.

Hydrology.—The ever increasing demands by industry, agriculture and domestic users for adequate supplies of water have focussed attention upon hydrology, and this science is being fostered in the Meteorological Office by wider study of what happens to precipitation after it has reached the ground. This wider interst was reflected in a paper on rainfall run-off and evaporation which was read by Dr. J. Glasspoole under the auspices of the British Water Works Association at the Public Works and Municipal Services Congress at Olympia, London, in November 1950.

Potato-blight warnings.—The weather of 1950 resulted in outbreaks of potato blight which reached epidemic proportions in many areas, but the warnings supplied by the Meteorological Office greatly assisted the planning of preventive spraying and much valuable food was saved. A recent Conference of Advisory Plant Pathologists, which discussed the system of potato-blight forecasting, expressed its appreciation of the information supplied, extended its thanks to all observers who had taken part and looked forward to co-operation along the same lines in 1951.

Inquiries from the Press and General Public.—The increasing use of meteorological information by the London Press and the General Public is shown by the number of inquiries received by the forecast section in Kingsway since the war. The number of inquiries dealt with there, mostly by telephone, were:—

Year	1946	1947	1948	1949	1950
No. of inquiries	14,503	23,815	23,145	32,307	43,612

In general, summer week-ends were the busiest periods, but 542 inquiries on the prospects of fog clearance were logged on November 25, 1950, and 495 on the likelihood of rain ceasing for the Test Match at Lords on June 23, 1950. The largest number of inquiries received in any one month was 5,044 in July 1950.

Falkland Islands.—The August 1950 *Meteorological Magazine* included a paragraph about meteorological work in the Falkland Islands and mentioned that assistants for the Falkland Islands Dependencies Survey were being recruited from amongst the Meteorological Office staff. As a result the following assistants were selected and left in the *John Biscoe* early in November: J. R. Cowling, J. Ford, B. D. Hunt, P. H. Hoare, A. F. Lewis, A. I. MacArthur, P. W. Mander, N. H. Thyer, R. A. Todd-White, and A. J. Vernum. A. F. Lewis, well known to his friends at home as the holder of the Air Ministry swimming championships for several years, has made an excellent start in his new sphere. On the trip from Port Stanley to his base, in the *John Biscoe*, he retrieved an indispensable roll of cable which had fallen overboard. The temperature of the water was 31°F.

Ocean weather ships.—The *Weather Recorder*, owing to a defect in her steering gear, was unable to manœuvre in the normal way when being relieved by *Weather Observer* at station JIG on January 11, 1951. As a result of this in a very heavy squall a sea was shipped over the stern of the *Weather Recorder* which damaged the doors leading into the balloon shelter and injured some of the crew. Fortunately the damage was superficial and the injuries not serious.

Thanks to the kind interest of Captain Fanshaw, R.N., the members of the Carlton Club have arranged to send magazines to the weather ships. The first gift has been received and sent to Greenock.

Awards to Staff by the Royal Humane Society.—We are pleased to be able to record that, in recognition of their attempts to rescue a man from drowning at Benbecula in August last, letters have been received by Messrs. D. M. Sadler and J. Meadows from the Chief County Constable of Inverness notifying them of the undermentioned awards from the Royal Humane Society:—

D. M. Sadler, the Society's bronze medal and bronze medal certificate.

J. Meadows, the Society's testimonial on vellum.

Examination successes.—We offer our congratulations to Messrs. A. A. Harrison and W. J. T. Norris on having passed the Intermediate B.Sc. Examination, London, in July last, and to Messrs. M. T. Batstone, A. D. Krill and A. C. Roberts on passing the same examination in November.

WEATHER OF JANUARY 1951

Mean pressure was above 1020 mb. over an area extending from Morocco and southern Portugal across the Azores, Bermuda and the south-east of the United States to northern California, with an extension north-westwards across Saskatchewan to the Arctic Ocean. It was below 1000 mb. between the Hebrides and southern Greenland and slightly below 990 mb. over a small area south-west of Iceland.

The mean pressure was slightly above normal over most of the North Atlantic between Portugal and the south-east of the United States, but was below normal over the greater part of North America and considerably below normal over most of the Mediterranean and Europe and from the Bay of Biscay and the western coasts of the British Isles north-westwards to southern Greenland. The deficit was 8 or 9 mb. over the British Isles and much of central Europe, and about 10 mb. over the Atlantic in about 60°N. from 10°W. to nearly 40°W.

In the British Isles the weather was rather cold except in the south-east, though not nearly as cold as the previous month. It was unsettled and wet on the whole, with considerable snowfall at times, but sunshine appreciably exceeded the average in Northern Ireland and locally in the north and east of Scotland and north-east England.

In the early hours of the 1st a secondary depression over north Wales moved slowly north and was associated with rather heavy snowfall in Northern Ireland, north Wales, the Midlands and north-west England; at 0900 on the 1st snow lay to a depth of 12 in. at Buxton, 10 in. at Malham Tarn and 8 in. at Lake Vyrnwy. During the 1st another centre of low pressure moved along the English Channel, and on the 2nd yet another moved east over the south of England to Holland and then turned north-east. Snow occurred in southern England and the Midlands, and lay 10½ in. deep at Whipsnade and 8 in. at Birmingham on the morning of the 2nd, and 11½ in. and 9 in. respectively on the morning of the 3rd. This period was very cold generally, temperature in the screen falling to 8°F. at Houghall, County Durham on the 2nd. A gale occurred at the mouth of the English Channel on the 1st. On the 4th and 5th a trough to a depression south-westward of the British Isles moved north over southern England causing heavy rain, and on the 6th the main depression, now centred south of Ireland, moved quickly north-east giving further rain. Gales were recorded locally on the south-west coasts and temperature rose in southern districts but remained low in the north. Thereafter a trough of low pressure moved east across the country giving more rain. On the 10th a depression, which had developed over the south of Ireland, moved north-east across Scotland, while an associated trough crossed England. Heavy precipitation occurred in the west and north on the 9th (2·04 in. at Kilsyth, Stirlingshire) and more generally on the 10th; in Scotland snow fell up to a foot deep in places on the 10th. On the 11th a deep depression south-west of Iceland moved a little south-east and a trough crossed England; more precipitation occurred and rainfall was moderately heavy locally; gales were registered at times at exposed places from the 10th to the 12th. Subsequently a depression south of Iceland moved east and a spell of showery weather ensued, snow showers occurring in the north. A ridge of high pressure moving east on the 15th was associated with a mainly fair day. The ridge was quickly followed by a trough which caused heavy rain in the west and north on the 16th and 17th (3·85 in. at Kinlochquoich, Inverness-shire, and 2·50 in. at Sloy Power Station, Dumbartonshire on the 16th and 2·87 in. at Kinlochquoich on the 17th), while temperature rose considerably throughout the country. The mild weather persisted during the ensuing days with pressure high off Spain and depressions moving east off the north of Scotland. Rainfall was generally slight over most of England, Wales and Ireland but heavier in parts of Scotland. Gales were registered locally at times on the 17th and 18th. On the 22nd and 23rd a depression moved from north-westward of Ireland to the Bay of Biscay; some rain fell in Ireland and southern England. Subsequently pressure became high in a belt across Great Britain; temperature fell and there was fog in the Midlands and the north on the 24th. On the 25th and 26th a trough moved slowly across the country giving precipitation in most areas, heavy locally in the west. On the 27th a depression off our south-west coasts moved away south-east giving some precipitation in the west and another ridge built up over the British Isles; temperature fell decidedly and there was considerable fog and severe frost. In the closing days a trough moved over western districts but weather continued mainly cold except in the west.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	58	8	−0·5	127	+2	93
Scotland	54	11	−1·9	130	+1	104
Northern Ireland ...	54	16	−1·7	112	0	121

RAINFALL OF JANUARY 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·84	153	*Glam.*	Cardiff, Penylan ...	5·33	144
Kent	Folkestone, Cherry Gdn.	3·52	156	*Pemb.*	Tenby	6·00	160
,,	Edenbridge, Falconhurst	3·52	144	*Card.*	Aberystwyth	4·05	126
Sussex	Compton, Compton Ho.	5·01	158	*Radnor*	Tyrmynydd	7·03	112
,,	Worthing, Beach Ho. Pk.	3·37	145	*Mont.*	Lake Vyrnwy	6·86	119
Hants.	Ventnor, Roy. Nat. Hos.	4·43	172	*Mer.*	Blaenau Festiniog ...	12·06	118
,,	Bournemouth	3.22	119	*Carn.*	Llandudno	2·70	112
,,	Sherborne St. John ...	2.95	127	*Angl.*	Llanerchymedd ...	3·88	123
Herts.	Royston, Therfield Rec.	2·49	144	*I. Man*	Douglas, Borough Cem.	5·30	158
Bucks.	Slough, Upton	2·82	152	*Wigtown*	Port William, Monreith	4·59	140
Oxford	Oxford, Radcliffe ...	3·07	170	*Dumf.*	Dumfries, Crichton R.I.	5·62	175
N'hants.	Wellingboro' Swanspool	2·38	129	,,	Eskdalemuir Obsy. ...	7·87	146
Essex	Shoeburyness	1·40	104	*Roxb.*	Kelso, Floors	3·09	177
,,	Dovercourt	1·83	114	*Peebles*	Stobo Castle	4·01	133
Suffolk	Lowestoft Sec. School ...	2·04	122	*Berwick*	Marchmont House ...	3·73	166
,,	Bury St. Ed., Westley H.	2·26	126	*E. Loth.*	North Berwick Res. ...	2·82	164
Norfolk	Sandringham Ho. Gdns.	2·85	147	*Midl'n.*	Edinburgh, Blackf'd. H.	2·59	147
Wilts.	Bishops Cannings ...	2·95	127	*Lanark*	Hamilton W. W., T'nhill	3·72	113
Dorset	Creech Grange... ...	4·41	135	*Ayr*	Colmonell, Knockdolian	4·49	104
,,	Beaminster, East St. ...	4·40	126	,,	Glen Afton, Ayr San. ...	6·02	118
Devon	Teignmouth, Den Gdns.	3·26	112	*Bute*	Rothesay, Ardencraig ...	5·93	132
,,	Cullompton	3·62	112	*Argyll*	Morvern (Drimnin) ...	9·39	148
,,	Ilfracombe	4·80	146	,,	Poltalloch	6·72	133
,,	Okehampton Uplands	7·29	143	,,	Inveraray Castle ...	8·44	103
Cornwall	Bude, School House ...	4·92	162	,,	Islay, Eallabus	5·53	118
,,	Penzance, Morrab Gdns.	6·10	161	,,	Tiree	8·65	204
,,	St. Austell	5·32	124	*Kinross*	Loch Leven Sluice ...	4·80	152
,,	Scilly, Tresco Abbey ...	5·31	169	*Fife*	Leuchars Airfield ...	3·12	171
Glos.	Cirencester	4·12	164	*Perth*	Loch Dhu	8·87	97
Salop.	Church Stretton ...	2·54	97	,,	Crieff, Strathearn Hyd.	4·71	117
,,	Shrewsbury	1·89	97	,,	Pitlochry, Fincastle ...	2·75	79
Worcs.	Malvern, Free Library	2·43	110	*Angus*	Montrose, Sunnyside ...	3·76	189
Warwick	Birmingham, Edgbaston	3·01	149	*Aberd.*	Braemar	3·31	104
Leics.	Thornton Reservoir ...	2·44	123	,,	Dyce, Craibstone ...	4·01	170
Lincs.	Boston, Skirbeck ...	3·28	202	,,	Fyvie Castle	3·35	141
,,	Skegness, Marine Gdns.	2·83	164	*Moray*	Gordon Castle	2·77	137
Notts.	Mansfield, Carr Bank ...	1·85	86	*Nairn*	Nairn, Achareidh ...	2·26	125
Derby	Buxton, Terrace Slopes	5·22	117	*Inverness*	Loch Ness, Garthbeg ...	4·73	107
Ches.	Bidston Observatory ...	1·80	85	,,	Glenquoich	12·46	91
Lancs.	Manchester, Whit. Park	3.23	129	,,	Fort William, Teviot ...	9·73	100
,,	Stonyhurst College ...	5·09	119	,,	Skye, Duntuilm ...	7·65	144
,,	Squires Gate	3·93	151	*R. & C.*	Tain, Tarlogie House ...	3·13	128
Yorks.	Wakefield, Clarence Pk.	1·81	94	,,	Inverbroom, Glackour...	5·89	110
,,	Hull, Pearson Park ...	1·72	95	,,	Applecross Gardens ...	8·45	154
,,	Felixkirk, Mt. St. John...	1·83	91	,,	Achnashellach	9·25	102
,,	York Museum	1·91	108	,,	Stornoway Airfield ...	4·95	101
,,	Scarborough	1·97	98	*Suth.*	Loch More, Achfary ...	7·69	106
,,	Middlesbrough... ...	1·69	106	*Caith.*	Wick Airfield	2·62	107
,,	Baldersdale, Hury Res.	3·15	97	*Shetland*	Lerwick Observatory ...	5·19	122
Norl'd.	Newcastle, Leazes Pk....	1·03	52	*Ferm.*	Crom Castle	3·93	118
,,	Bellingham, High Green	3·11	109	*Armagh*	Armagh Observatory ...	2·65	105
,,	Lilburn Tower Gdns. ...	2·46	119	*Down*	Seaforde	4·50	143
Cumb.	Geltsdale	3·78	135	*Antrim*	Aldergrove Airfield ...	2·47	90
,,	Keswick, High Hill ...	4·67	92	,,	Ballymena, Harryville...	3·57	96
,,	Ravenglass, The Grove	4·16	124	*L'derry*	Garvagh, Moneydig ...	4·52	131
Mon.	Abergavenny, Larchfield	4·34	128	,,	Londonderry, Creggan	4·15	115
Glam.	Ystalyfera, Wern House	8·74	138	*Tyrone*	Omagh, Edenfel ...	3·52	99

M.O. 548 AIR MINISTRY

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ESSAY ON FRONTOGENESIS AND FRONTOLYSIS

By H. H. LAMB, M.A.

Part III

Frontolysis.—Frontolysis has tended to be dismissed in meteorological literature as a mere counterpart of frontogenesis, to be explained in terms of the same deformation field. The subject is worth separate study.

We have already noticed that the frontolytic col seldom arises in practice.

Fig. 12, which shows a front, A, lying quasi-stationary between the twin centres of an intense anticyclone over England and France on February 14, 1946, probably typifies an unusually close approach to the frontolytic orientation of a front in the col. It was not at once clear whether the situation would prove frontolytic, but the intensely anticyclonic conditions ensured that the front would be quiescent. At the time of the chart shown in Fig. 12, the situation had already existed substantially unchanged for more than 24 hours, yet the front A is still marked by a sharp wind discontinuity. Eight hours later a small movement of the front west of Hurn airport brought a wind veer from NE. to S. and eventually to SW. and a sharp deterioration of visibility as the smoke from Bournemouth and Poole was transported in the direction of the airfield. At the same time, the low stratus lifted from about 500 to 1,000 ft. with the arrival of the drier continental air mass. Dew points over France were mainly between 20° and 30°F., and the dry-bulb temperatures show the effect of radiation cooling in the area of clear skies on Fig. 12, but approached the level of the warm-air temperatures in the strip of territory near the front covered by a frontal cloud sheet in the form of 10 tenths stratocumulus. Dew points in the warm air mass ranged from 42° to 48°F. and there was much fog in this air mass and at the front.

On the 15th the two high centres coalesced and it became impossible to trace the front in the central region where the surface winds fell calm and fog was widespread. Nevertheless the difference between the air masses remained, and when the continental air mass reached Brest the dew point there fell below 40°F. on the morning of the 15th. A study of the upper air temperatures over Brussels, Paris, Bordeaux and Toulouse revealed the continued existence of the frontal surface aloft throughout the life of the anticyclonic system, details on the 14th at 0500–0600 being:—

Brussels: inversion of 6°F., base 2,700 ft.
Paris: inversion of 2°F., base 2,000 ft.
Bordeaux: isothermal layer, base 2,000 ft.

It is worth noticing that the discontinuity is sharpest at Brussels in the centre of the high, where subsidence had sharpened the discontinuity surface aloft.

The surviving air-mass difference again became noticeable further west as a weak frontal line on the 16th, when the anticyclonic centre drifted away south-westwards before the main Atlantic cold front advancing from the north. Fig. 13 shows the situation at 0900 on the 16th, when drier and cooler air had reached the Scilly Isles from the west around the centre of the high, and the weak frontal line in the mouth of the English Channel marked the edge of the stratus-covered skies in the warm tropical maritime air mass still streaming eastwards through a narrowing corridor over England and Ireland towards the Continent. R.M.S. *Queen Elizabeth* in 49–50°N. and 18–19°W. was also in the drier air mass affecting Scilly and had only broken cloud above 5,000 ft. with light westerly breezes. At the same time the weak warm front was pressing south and south-westwards over France with a belt of particularly low ceilings (300–600 ft.) and poor visibility (less than a mile) nearing Bordeaux, a major consideration for aircraft approaching that area.

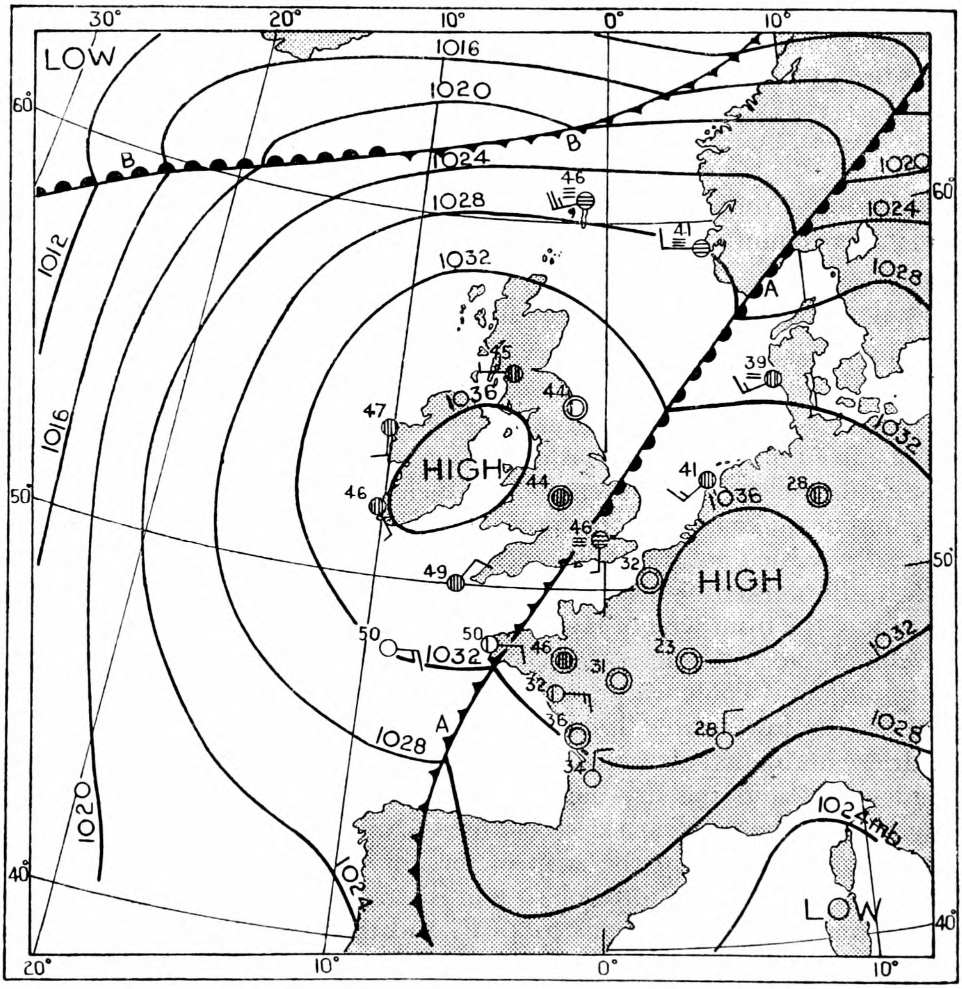
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FIG. 12—SYNOPTIC CHART, 0600 G.M.T., FEBRUARY 14, 1946

Nevertheless, in spite of the way the front, in the example we have just considered, was partially regenerated after surviving several days of what have generally been considered ideal frontolytic conditions, fronts commonly disappear from the charts. Some of them do so through a process that some American workers have called consolidation of several fronts into one. This is in reality a frontogenetic process in the sense that the resulting single front is sharpened by it. Secondary cold fronts almost habitually tend to catch up and become consolidated with the leading cold front or occlusion. Experience of Atlantic-Ocean weather analysis and forecasting shows that many of the secondary cold fronts which pass eastwards over Labrador and Newfoundland never reach Europe or the Azores as separate frontal systems, and consolidation is undoubtedly the reason for this in the vast majority of cases in winter time; in summer, it is probable that a number of secondary fronts, that are little more than internal convection lines within the cold air mass coming from the north Canadian territories where ground heating is at work at this season, die away completely when the air mass is stabilized over the cool sea. The frequent occurrence of consolidation comes about through the stronger pressure gradients which are more often seen across the rearward members of a succession of frontal systems than across the foremost members, a situation of which Fig. 5 gave a typical example. Consolidation is however something quite different from frontolysis.

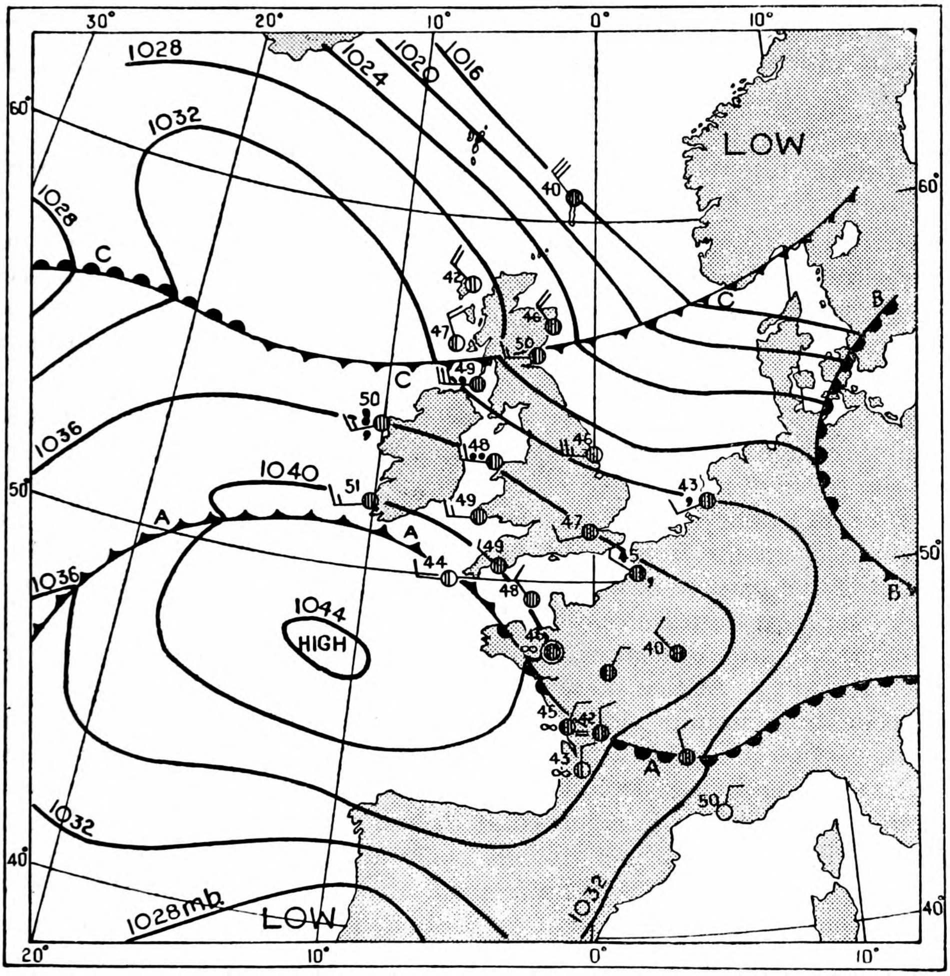
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FIG. 13—SYNOPTIC CHART, 0900 G.M.T., FEBRUARY 16, 1946

The fundamental condition for frontolysis is air-mass assimilation. If the air masses on either side of a given front become alike, the front disappears. Moreover this process is final; there is no special likelihood of a front ever being formed again in the same region; no transitional zone remains to favour such regeneration.

Frontolysis through air-mass assimilation will be brought about by any of the following circumstances:—

(*a*) stagnation of the air masses concerned, side by side over a single terrain, where both are subjected to like influences from the under surface and from direct radiation;

(*b*) movement of the air masses side by side along parallel tracks without any important difference of velocity between them, so that both undergo like influences;

(*c*) movement of the air masses one after the other over the same track without any important difference of velocity or shear — with a transverse orientation of the front;

(*d*) arrival of the front in a geographical region where the sense of the ground temperature gradient is unfavourable for its continued existence (this occurs where the air mass fed into the cold side of the front is as warm as, or warmer than, the air mass on the warm side; and, *vice versa*, when the warm-sector air mass encounters still warmer air ahead of it).

Cases (*a*), (*b*) and (*c*) are very similar in nature. Most rapid assimilation takes place where an adiabatic lapse rate is established. Consider Fig. 14, in which the curve of state PQRS represents a sounding through a shallow layer of cold air PQ underlying a warmer air mass RS at no very great distance horizontally from the front. This is a typical sounding for a north African station after the passage of a cold front bringing in a polar air mass from the Atlantic Ocean or from Europe, normally quite shallow in such latitudes. The effect of intense ground heating is already seen in the superadiabatic lapse rate between P and Q. At first there may have been a frontal cloud sheet of altocumulus or stratocumulus aloft, but, once enough rifts were made in this cloud to let the African sun get to work, the hot ground would soon change conditions in the lower layers of air. In a day or two surface temperatures of 85°F. might occur in place of the 64°F. recorded at P; and the curve P′RS would be substituted for PQRS, the former shallow polar air mass being obliterated by its entire transformation into African tropical air. The second curve LMNO in Fig. 14 is plotted from an ascent for Lisbon, Portugal (surface temperature 50°F.) after a cold front had come in from the Atlantic, and corresponds exactly to the African curve PQRS just considered. Surface heating over the Iberian peninsula to 79°F. would establish a dry adiabatic lapse rate from L′ to N and destroy the polar air mass. Finally, EFGH is the curve of an ascent made in a similar synoptic situation at Stornoway in the Hebrides. Here the prevailing humidity makes it probable that considerable amounts of convection cloud will accompany surface heating, and that the establishment of a saturated adiabatic lapse rate from E′ to G will follow from a warming of only 5°F.— from 40° to 45°F.— at the surface and destroy the colder air mass in the lower layers. The curves EFGH and E′GH also typify the development which takes place over the ocean when two air masses move or stagnate under conditions favouring assimilation.

The cases demonstrated in Fig. 14 are similar in nature to the events which led to the interruption of the subsidence surface B over Downham Market in Fig.9. It is worth noticing therefore that the interruption of the subsidence surface on the occasion referred to was to some extent a localized phenomenon, confined to places where the diurnal heating was strong enough, and, for that reason, it was possible for the continuity of the subsidence surface to be restored the following night. Similarly we should guard against assuming too readily that the first day's heating from the ground has completely destroyed a front, even over the African desert. Sections of the front over the Atlas Mountains for instance may have been much less weakened than over the open desert further south, particularly in winter if the shallow cold air has filled the shaded valleys. Activity on the front may continue for a while, or may become patchy, and the air-mass difference may take some days to disappear.

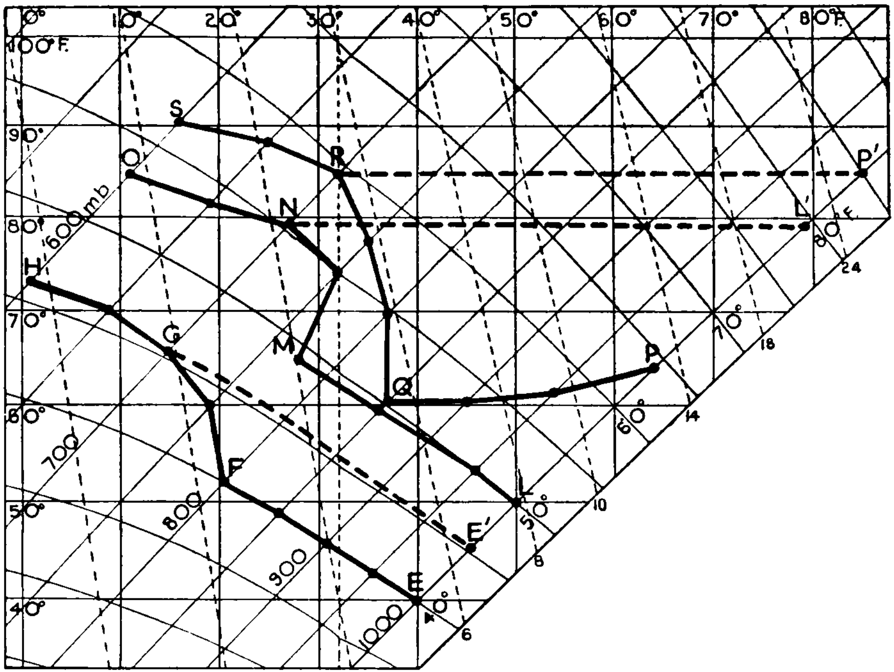

FIG. 14—TYPICAL TEPHIGRAMS OF ASCENTS OVER NORTH AFRICA, LISBON AND STORNOWAY AFTER THE PASSAGE OF A COLD FRONT

Subsidence assists frontolysis in so far as it creates the conditions of clear sky in which solar heating of the ground will be most effective. Downgliding over the frontal surface destroys the frontal cloud sheets, and turbulence cloud decks will be largely cleared away. Only moderate subsidence accompanied by strong heating from the ground should be most effective.

We may discern from Fig. 14 the conditions which favour or retard the conversion of shallow cold air masses and disappearance of the fronts and frontal surfaces which mark their limits. Great heating is needed to obliterate a cold air mass by establishing a dry adiabatic lapse rate from the surface up, but this heating is often available in Africa and, in summer, over the Iberian peninsula. Assimilation of shallow cold air masses then takes place. The shallower the cold air mass and the less pronounced the transition layer above it, the more readily and the sooner it is assimilated. Relics of the front or frontal surface may remain here and there where the cold air mass was relatively deep or where the heating was not strong enough to obliterate it. Less heating is required to establish, from the surface up, the saturated adiabatic conditions which correspond to total disappearance of a shallow cold air mass over the ocean. Assimilation occurs in this manner under suitable conditions over the wide oceans and also over large inland seas such as the Mediterranean.

The sequence of events following the invasion of the trade-wind belt over the North Atlantic in the region of the north-west African coast and the Canary Islands by a shallow cold air mass from high latitudes is extremely interesting. Although the surface air layers show the steep lapse rate of temperature associated with strong heating from below, the existence of a stable, frontal transition layer at no great height aloft, and sometimes as low as 2,000 ft., means that the normal trade-wind cumuli disappear and give place to clear skies or to a sheet of stratocumulus, if the invading air mass is deep enough to allow condensation within it. The normal appearance of the sky, with cumulus cloud predominating, is restored after a day or two when surface heating has had time to assimilate the shallow cold air mass to tropical temperatures.

The same course of events may be followed further west over the ocean when there are sufficient observations; but weak cold fronts which have been carried around the Azores anticyclone are still liable to be noticed at Bermuda. As in other cases, the deeper the cold air mass the longer the conversion to tropical air takes.

Shallow arctic air masses are converted to similarity with the air of middle latitudes in exactly the same way in the course of long transit or stagnation over the ocean west and south-west of the British Isles, traces of the former air-mass boundary being usually discernible for two or three days.

In high latitudes air masses may stagnate over a cold surface and develop surface temperatures approximating to those of the earth's surface. Stability and absence of turbulence will however maintain discontinuities aloft. One factor working against this and tending to establish adiabatic lapse rates is the radiation cooling direct from the cloud top, frequently proceeding from completely overcast layers. It seems, however, that air-mass assimilation in high latitudes proceeds only slowly, except where the air masses are in transit over open water of considerably higher temperature. Apart from this frontolysis is a slow process in the polar regions, and old weak frontal lines with residual cloud sheets and narrow belts of fog and snow maintain their existence over long periods.

Decay of a front due to unfavourable geographical factors (case (*d*)) usually comes about through the supply of air of progressively higher temperature beneath the frontal surface. For instance, when a warm front, bringing a sector of polar maritime or tropical maritime air from the Atlantic Ocean, moves south-east across Europe in winter there comes a point at which the continental cold air ahead of the front is replaced by air modified by having been over the warm Mediterranean Sea, and, ultimately perhaps, by air that has been over Africa; the warm front is not likely to survive much of this and the air-mass difference will soon be obliterated. Similar occurrences take place with equal regularity in other parts of the world, as when warm sectors — usually partly occluded — move south-east or east-south-east across the Rockies and encounter air from the Mexican Gulf or from the warm plains of Texas, and when old continental warm sectors reach the Atlantic seaboard of the United States in winter and meet the warm humid air brought northwards over the ocean by the Azores-Bermuda high.

A special type of frontolysis peculiar to occlusions has been described by Bergeron. At the completion of the occluding process horizontal convergence seems to set in within the uplifted warm air, accompanied by subsidence in the lower levels and lifting of the tropopause. This occurs in the former central regions of the depression where the tropopause had been sucked down. Rising pressure sets in, centred on the occlusion. The occlusion shown in Figs. 15–17 in the rear of the Skagerrak depression moved south over the British Isles on January 12–13, 1946, disappearing gradually under the persistent frontolytic effect of strongly rising pressures and clearing skies which helped the influence of the under surface, working alike on the two air masses moving over it. The charts represent the situation at 0600 on the 12th, soon after the pressure rises near the occlusion first became noticeable. The previously very sharp trough near the Shetland Isles has already shortened remarkably with a backing of the surface winds from E. to NNE. The association of the greatest rise of pressure (7·4 mb. in 3 hr.) with the occlusion is clearly seen in Fig. 16. The contours of the tropopause shown in Fig. 17 reveal a broad low area over the British Isles and the North Sea associated with the occluded depression centred

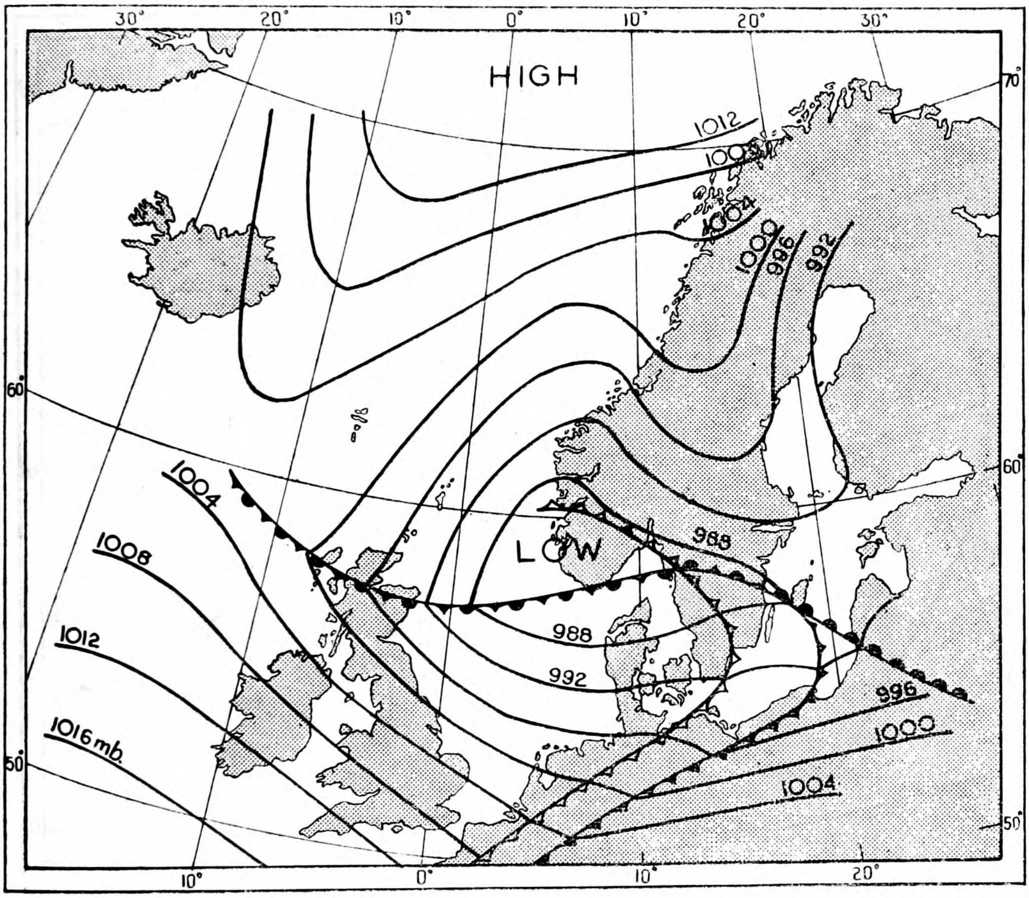

FIG. 15—SURFACE SYNOPTIC CHART, 0600 G.M.T., JANUARY 12, 1946

just further east, whilst the line of the upper front of the occlusion (trough-line of the lifted warm sector) — placed on the surface map on the basis of pressure-tendency characteristics and distribution of snowfall over Norway — corresponds to a distinct ridge on the tropopause. The front disappeared in 36 hr. A very similar synoptic situation on August 25, 1945, led to much more rapid dissolution of the occlusion moving south over Great Britain and the North Sea, probably owing to the much more effective heating influence of the ground in summer assimilating the air masses, although the isallobaric effect was a good deal weaker.

Examples are not uncommon over southern Canada in which a long occlusion trailing from a depression over Newfoundland dissolves in the section between the depression centre and the Great Lakes, whilst the western end of the same front is maintained over Alberta as a sharp boundary between the Canadian and Pacific polar air masses. Examples have also been described elsewhere[14].

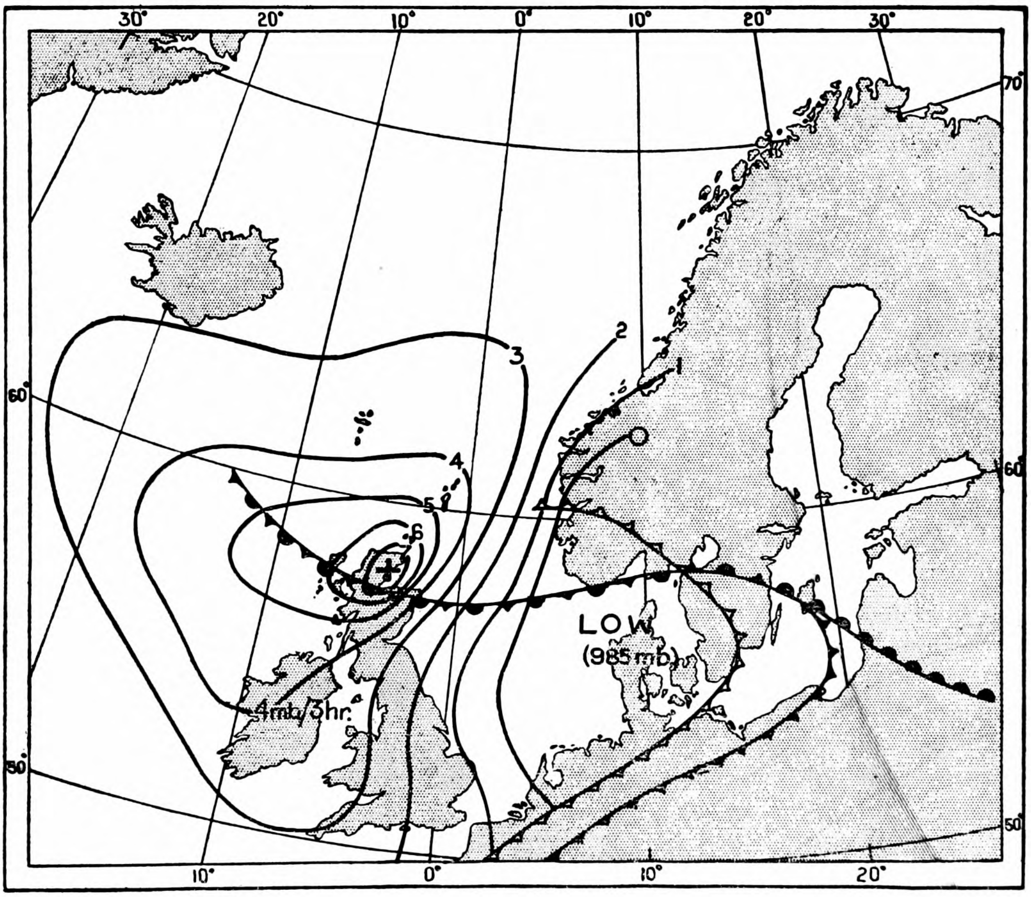

FIG. 16—ISALLOBARS, 0600 G.M.T., JANUARY 12, 1946

Conclusion.—We have surveyed some of the vicissitudes in the life history of fronts. Many more would come to light in any detailed study of the vertical motions and smaller circulations near the frontal surface. Nevertheless we may usefully sum up our general picture of the life history of a front.

A major frontal system is not easily formed, and, once formed, does not easily die away. In some circumstances both events do take place rapidly. More usually the frontal system travels far across the earth between its birth and decay and undergoes successive frontogenetic and frontolytic influences, which alternately strengthen and weaken its activity. It suffers, too, continual distortions and changes of slope, as cyclonic disturbances develop and move along it. As the frontal system makes its way around the world, the nature of the air masses fed into it on either side is continually changing. The activity of the front changes in consequence, but it does not necessarily lose its identity.

The occlusions of north-west Europe advancing east and south-east across the continent may eventually appear as cold fronts sweeping across China from the heart of Asia, as has been testified by Chinese investigators[15]. Other similar systems get steered south over European Russia and the Black Sea, and arrive, usually as cold fronts, in the autumn, winter and spring seasons in the eastern Mediterranean.

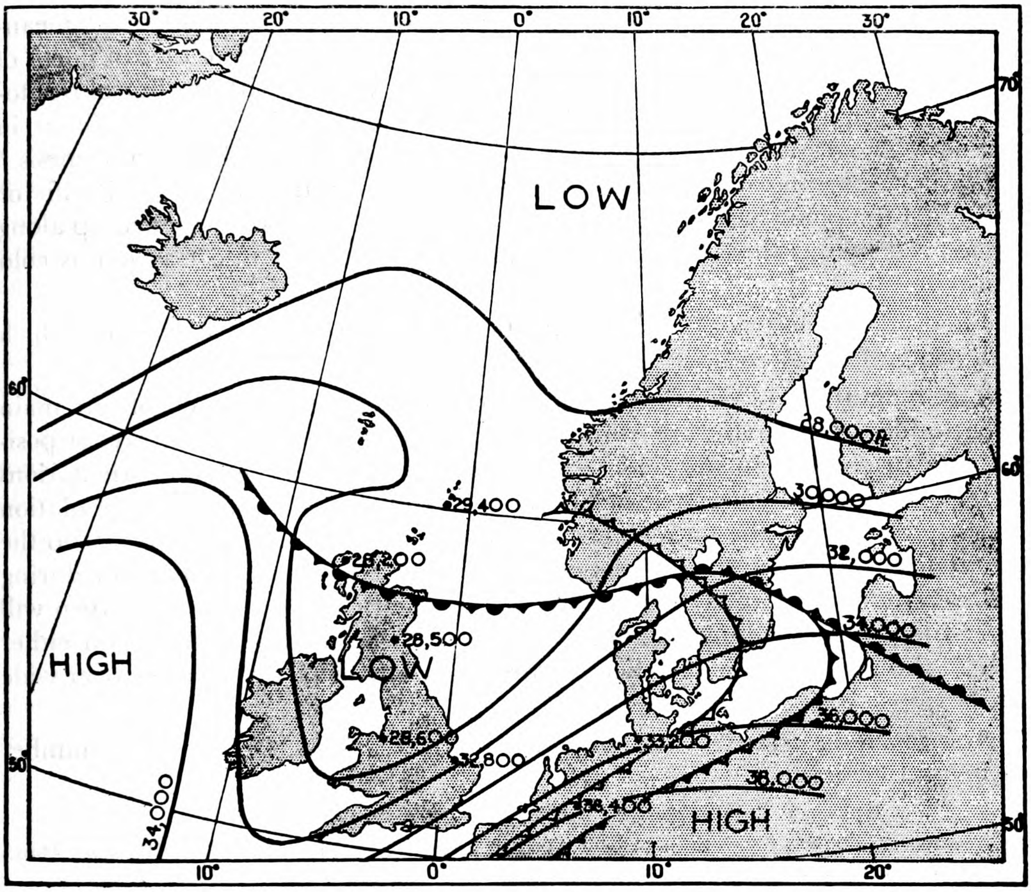

FIG. 17—CONTOURS OF TROPOPAUSE, 0600 G.M.T., JANUARY 16, 1946

We find ourselves constantly referring to these fronts emerging from their transformations as cold fronts, because the major, intercellular fronts maintained between the chief anticyclonic areas normally advance eastwards in successive stages as cold fronts and cold occlusions, the air masses in their rear being drawn from higher latitudes than the air masses ahead of them.

The frontal sequences in North America are interesting for the great frequency with which new systems enter that continent on one or other of two clearly defined courses. Occlusions, orientated parallel to the great Rocky Mountains barrier, advance on an eastward track. They represent the last stage of former Pacific-Ocean storms, but they begin a new phase of their existence east of the mountains when deformations are induced on them, either by topographical disturbances of the wind distribution or by the influence of other circulations. In winter these are warm occlusions, and are often followed by the föhn wind, " chinook". The other dominant feature of the North-American sequences is provided by the cold fronts which come in from the arctic shores of northern Canada and sweep south or south-east across the continent east of the Rockies. These fronts, too, are believed to originate as the occlusions of depressions which have come from elsewhere, sometimes merely on a circuitous track from the Davis Strait west of Greenland around the north of Baffin Land and the Canadian Archipelago but more often on longer tracks across the Arctic Ocean. Sverdrup[16] has noticed that climatological mean-pressure charts for the winter months show a col, in the Arctic Ocean north of Alaska, between the Canadian and Siberian anticyclones with the line of frontogenesis running south-east into Hudson Bay. This coincides with (*d*)(i) in our list of geographical belts of strong thermal gradient favouring frontogenesis.* Occlusions pushing northwards through the Bering Strait from the Pacific or rounding the polar basin from the North Atlantic would be sharpened up along some such line as this, and might then strike southwards into Canada as cold fronts.

Finally, we may notice an application to the considerations with which long-range forecasters will have to deal.

The magnitude of the thermal gradients associated with each of our main geographical belts favouring frontogenesis, as well as details of their precise position and orientation in any given season, must affect the strength and orientations of the jet streams arising in association with them, and therewith the circulation index. In so far as the pattern fits a stationary wave-length appropriate to the circulation index we may expect the pattern to be stable or recurrent during that season or at that particular time of the year. This pattern in its turn will determine the prevailing locations of axes of high and low pressure on either side of the jet streams and hence the broad character of the weather over wide areas.

Acknowledgement.—I am indebted to Mr. C. K. M. Douglas for a number of helpful criticisms.

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STANDING WAVES AND POWERED FLIGHT

By H. S. TURNER, B.A.

It has been known for some years by glider pilots that the most favourable conditions for soaring are to be found in what have come to be described as "standing waves" in an air stream, and heights of well over 30,000 ft. have been reached by sailplanes circling in such waves.

Several writers have made reference to the importance of this effect to glider pilots[1], but the possible result of such waves on the flight of powered aircraft has received little attention to date. It is the purpose of this note to place on record that discussions during the past two years or so with pilots operating from Northolt have revealed that the effect on powered aircraft may be very well marked on some occasions. Difficulty in maintaining prescribed heights has been reported by pilots from time to time in areas near and to the lee of high ground. Such reports have come in from Scotland, northern England, Wales, the Rhône Valley, Iberia and the south-Biscay area. The most striking instance reported at Northolt occurred on October 25, 1949, at 1130 G.M.T. over south Biscay (between 43½°N., 7°W. and 45°N., 6°W.) at about 10,000 ft. when a Viking aircraft, climbing at full power, lost 200 ft. in height in about 2 min., corresponding to a downward component of air flow of 1,100 ft./min. approximately. In general, such effects are less extreme than this example, and a more typical case would be such as occurred between Carlisle and Manchester on February 24, 1949, when height fluctuations of 500 ft. were experienced by a pilot ostensibly flying level at 9,500 ft.

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*See p. 38 in Part I in the February issue.

It is not intended to be meticulous or exhaustive on the subject at this stage since the information which has been gathered is not in general of an exact quantative nature. However, consideration of the reasonably clear-cut cases supports the following conclusions. These are in general agreement with the account given by A. E. Slater.[1]

(*a*) Standing waves are most likely to occur to the lee of hill ranges when a stable layer of air is flowing over a shallow unstable layer. Another condition which favours their formation is a fast-flowing air stream.

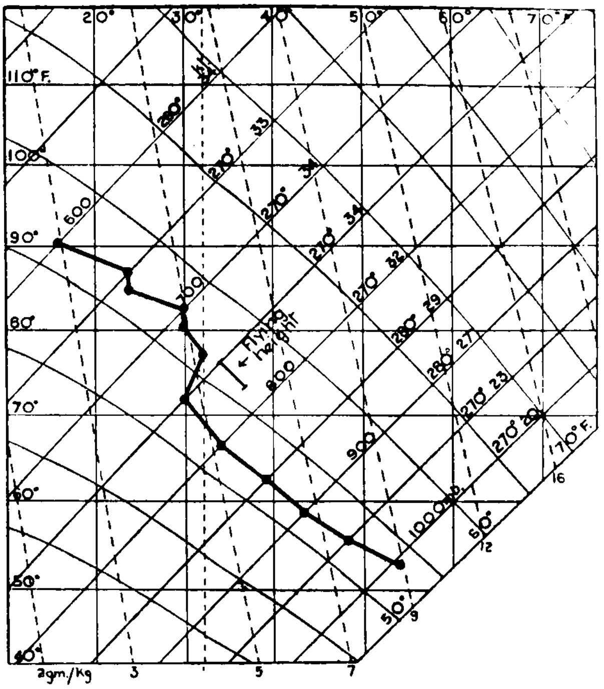
(*b*) In such conditions the air in the stable layer flows in stationary waves for some considerable distance to the lee of the hill range, the effect having been observed 60–80 miles away. The usual wave-length appears to be of the order of 5–10 miles.

(*c*) In most cases the air flow in standing waves is beautifully smooth from the flying point of view, but turbulence, if it does occur, may be very vigorous. There is some evidence to support the idea that when turbulence does occur, it is most likely in the vicinity of the crests and troughs of the waves, but more investigation is required to confirm this. The idea, however, is consistent with the type of flow envisaged by Prof. G. Manley[2] in his researches on the standing waves in the Helm wind of Cross Fell.

To date, Northolt pilots have reported twelve occurrences which were, indisputably, standing waves. Details of some of these and representative upper air soundings are given in Figs. 1–3. All occurred in areas to the lee of high ground. In seven of them it was known that the aircraft was flying in a stable layer, often nearly isothermal. In five other cases inadequacy of upper air information leaves some doubt as to the lapse rate, but in most of them stability was probable and on no occasion was it unlikely.

The depth of the lower (i.e. unstable) layer was variable, but usually exceeded 2,500 ft. and often reached 6,000 ft., this height being greater than most of the high ground from which the waves originated.

Any examination of the wind structure associated with a standing wave is complicated by uncertainty as to whether or not the area in which the soundings were taken was itself affected by the standing wave. No claim is made that the winds examined give information of anything but the general wind stream, and in this respect the conclusions would seem to have no bearing on the work of R. S. Scorer[3].



NOTES

Pilot reported difficulty in maintaining flying height.

Area—Peebles to Nottingham

Time—0845–0945 G.M.T.

Flying height—7,000–8,000 ft.

Navigator's wind—275°45 kt.

Cloud—8 oktas in banks running approximately 170–350°, thin St above and continuous with it, tops 5,000–7,000 ft. 8 oktas as above.

FIG. 1—TEPHIGRAM OF ALDERGROVE ASCENT, 0900 G.M.T., SEPTEMBER 29, 1948

The winds examined showed an average wind change of 4° and 5 kt. in the 50-mb. layer centred at the flying height, whilst the average change through the stable layer was 5° and 10 kt. It therefore seems improbable that vertical wind shear in the general stream plays any significant part in the formation of standing waves.

NOTES

Pilot reported height variations of 800 ft. despite avoiding action.

Area—Renfrew to Midlands.

Time—1800–2030 G.M.T.

Flying height—7,500 ft.

Navigator's wind—285 55 kt.

Cloud—Sc, tops to 6,500–7,000 ft.; occasional Cu to 8,000 ft.

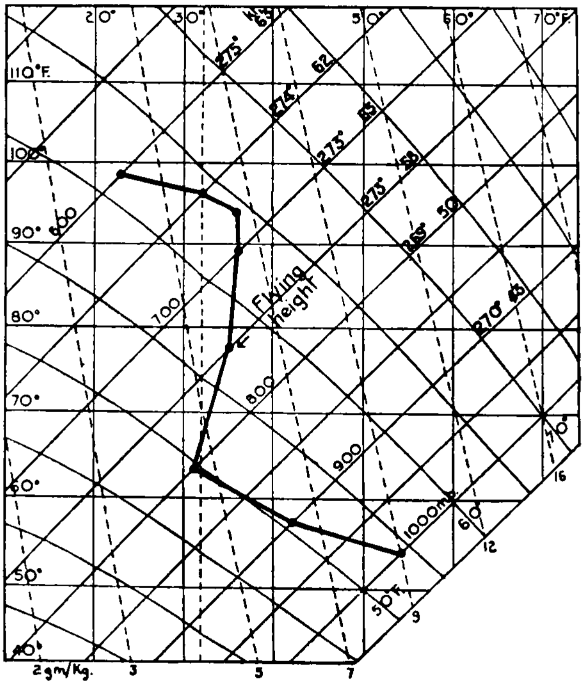
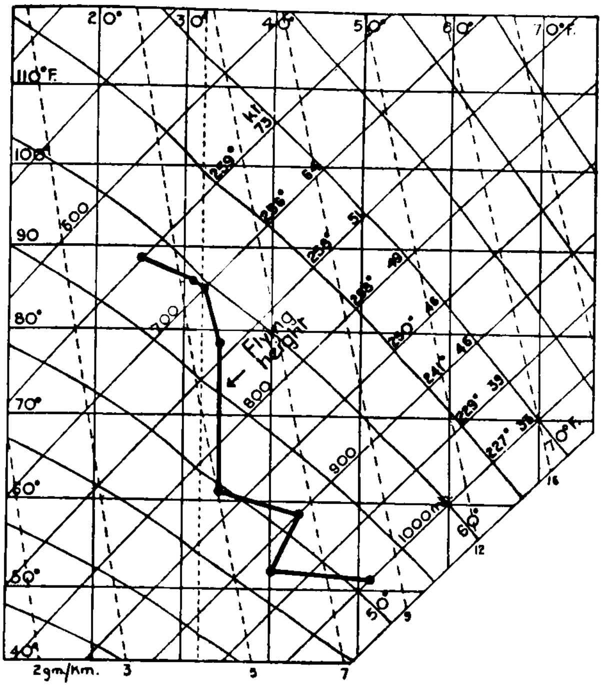


FIG. 2—TEPHIGRAM OF ALDERGROVE ASCENT, 1400 G.M.T. APRIL 20, 1949



NOTES

Pilot reported " considerable vertical motion ".

Area—East Wales.

Time—1200 G.M.T.

Flying height—7,000 ft.

Cloud—8 oktas Sc, tops 5,000 ft. but 6,500–7,000 ft. over hills.

FIG. 3—TEPHIGRAM OF LIVERPOOL ASCENT, 0800 G.M.T., FEBRUARY 16, 1950

An extremely striking feature of standing waves is that they are effective to surprisingly great heights on some occasions, with the stratospheric air stream flowing, possibly, in sympathetic waves. A height of 37,500 ft. was attained in 1940 by a glider pilot[4] in a strong stable southerly air stream to the lee of the Alps. It seems distinctly possible, therefore, that at least some of the cases of clear-air turbulence reported by high-speed powered aircraft at great heights may be associated with the crests and troughs of standing waves in suitable air streams and localities.

I wish to acknowledge the assistance given me by captains of the British European Airways Corporation; in particular, Capt. T. McKenzie, whose observations prompted this study.

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METEOROLOGICAL OFFICE DISCUSSION

Temperature and humidity in the lowest hundred metres of the atmosphere

The discussion on February 12, 1951, dealt with the measurements of temperature and humidity gradient at Rye in the lowest hundred metres of the atmosphere. The opening speaker was Mr. A. C. Best.

During the early part of the war it became apparent that the temperature and humidity structure of the lowest layers of the atmosphere may have a marked effect on the propagation of the centimetric radio waves. The characteristic features of the temperature structure of the lowest layers were already well known, but there was very little information available about the humidity structure in this layer. To obtain this information electrical-resistance thermometers and Gregory humidiometers were mounted at four heights on a steel latice tower extending to a height of 350 ft. at Rye. The records obtained from these instruments over a period of three years have been analysed.

The temperature records confirmed the general features found in earlier work. During the middle of the day there is normally a lapse of temperature, the lapse rate decreasing upwards. At night there is generally an inversion. The change over from inversion to lapse and *vice versa* occurs shortly after sunrise and shortly before sunset. The magnitude of the midday lapse is greatest in summer and least in winter. It is notable that during the winter the temperature gradient in the lowest part of the region considered remains positive or zero even during the middle of the day.

Curves showing the frequencies of temperature gradients of various magnitudes demonstrate the much wider range of temperature gradient very near the surface than at greater heights in the layer considered. At all heights in the first hundred metres the most frequent temperature gradient is a lapse rate with a value between the saturated-adiabatic lapse rate and zero.

During daylight hours there is a lapse of absolute humidity in the lowest layers of the region considered, the lapse rate being greater in summer than in winter. In this respect the humidity structure is similar to the temperature structure. Similarly the lowest layer usually experiences an inversion of humidity gradient at night. In the upper part of the first hundred metres however there is usually a lapse of humidity even at night. This lapse of humidity in the region 50–100m. is small throughout the day, in fact may be zero occasionally except during the months August to October.

During the summer months both the humidity lapse rate and the absolute humidity pass through two maxima in each 24 hours, one in the early morning just after sunrise and another in the afternoon. The early morning maxima arises from the increased rate of supply of water vapour from the surface as the temperature rises. The afternoon maximum is probably caused by the action of turbulence bringing water vapour down from a region above the first hundred metres.

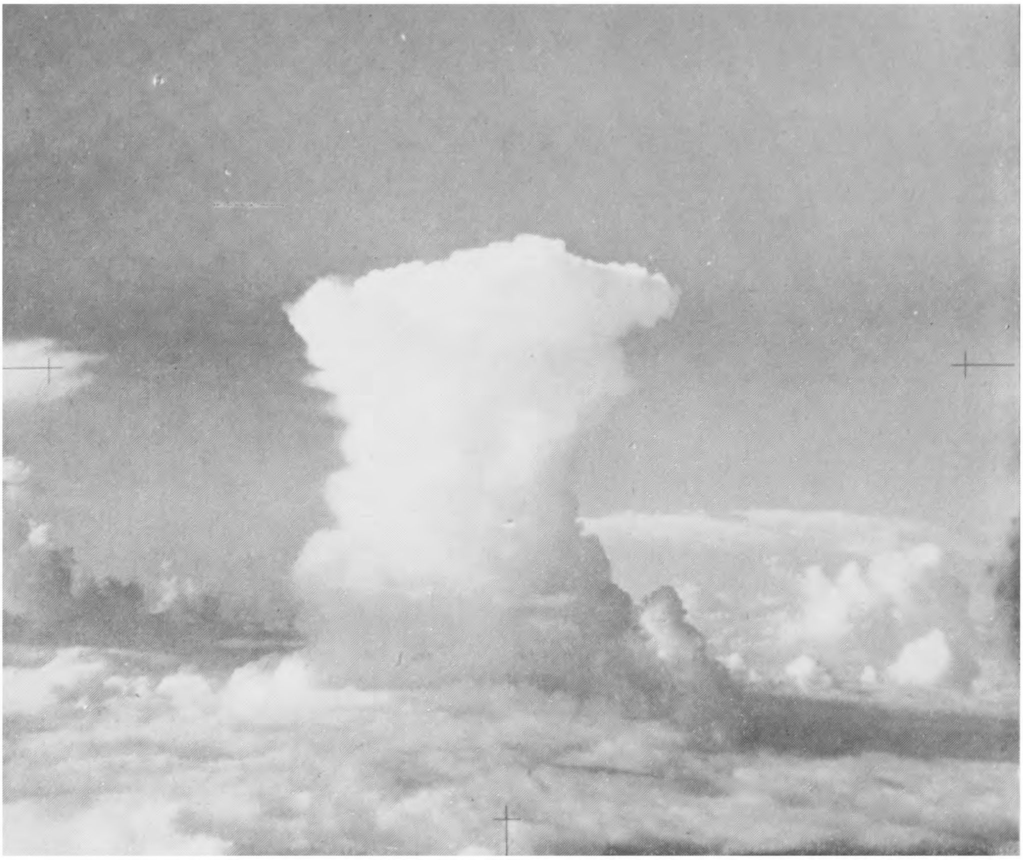
As in the case of temperature the frequency diagrams showed a much wider range of humidity lapse rate in the lowest layers than at greater heights, but at all levels the most frequent gradient of water vapour is zero.

The Director, opening the discussion, asked how the humidity elements were calibrated and how stable they were. The Director also indicated that it is hoped to use the installation at Rye for an investigation of the formation of fog. Mr. Best said that the humidity elements were calibrated periodically against an Assmann psychrometer. Generally the error was two per cent. to six per cent. but the humidity element was liable to show a rapidly increasing error after six to twelve months. When this happened the element was replaced. This deterioration of the element was hastened if a very wet fog was experienced.

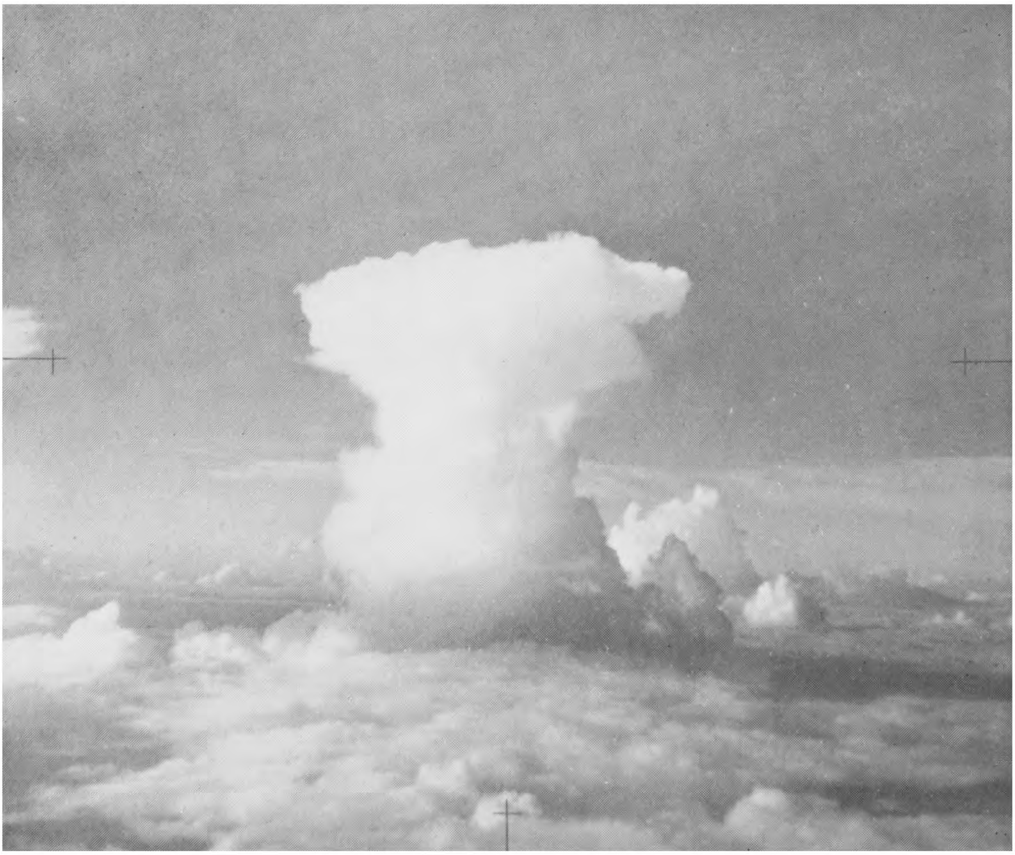
Photograph by Royal Aircraft Establishment

CONDENSATION TRAILS AND THEIR SHADOWS ON A SHEET OF ALTOCUMULUS

The photograph was taken looking westwards and upwards from the Royal Aircraft Establishment, Farnborough, at 1415 G.M.T., December 20, 1949. (see p. 119).



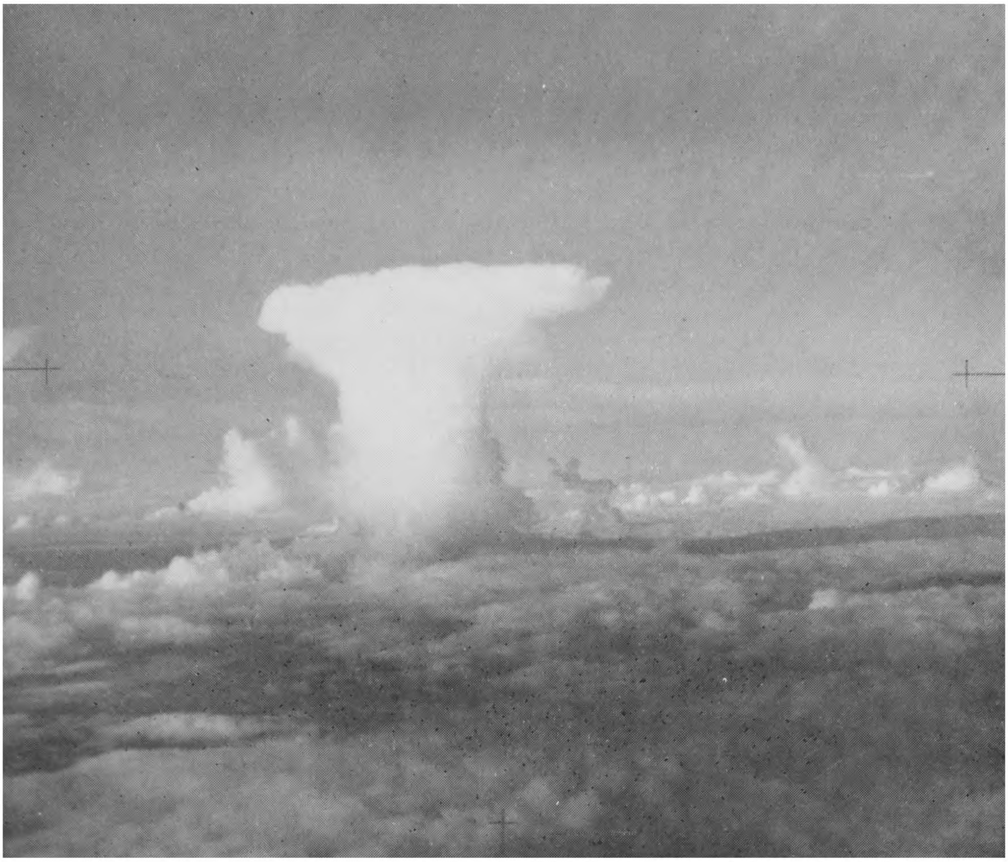
Near view of large cumulus developing into cumulonimbus



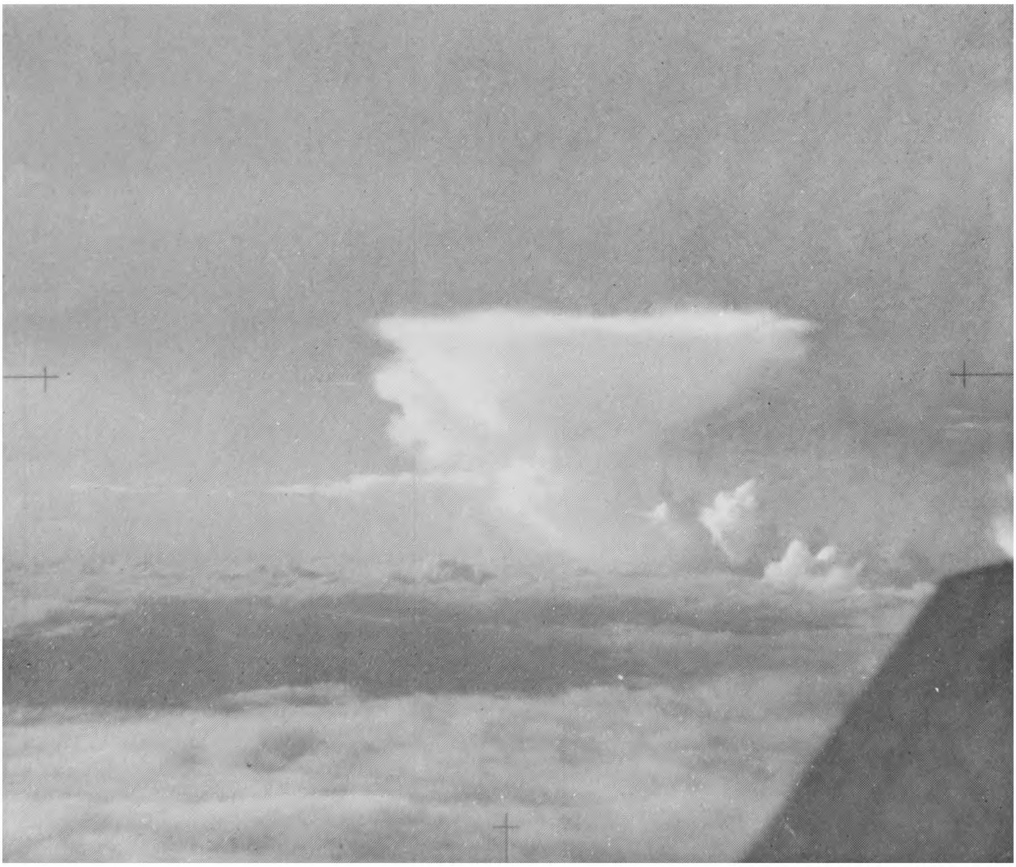
Same cloud after a short interval

DEVELOPMENT OF AN ISOLATED CUMULUS INTO A

All photographs were taken from a height



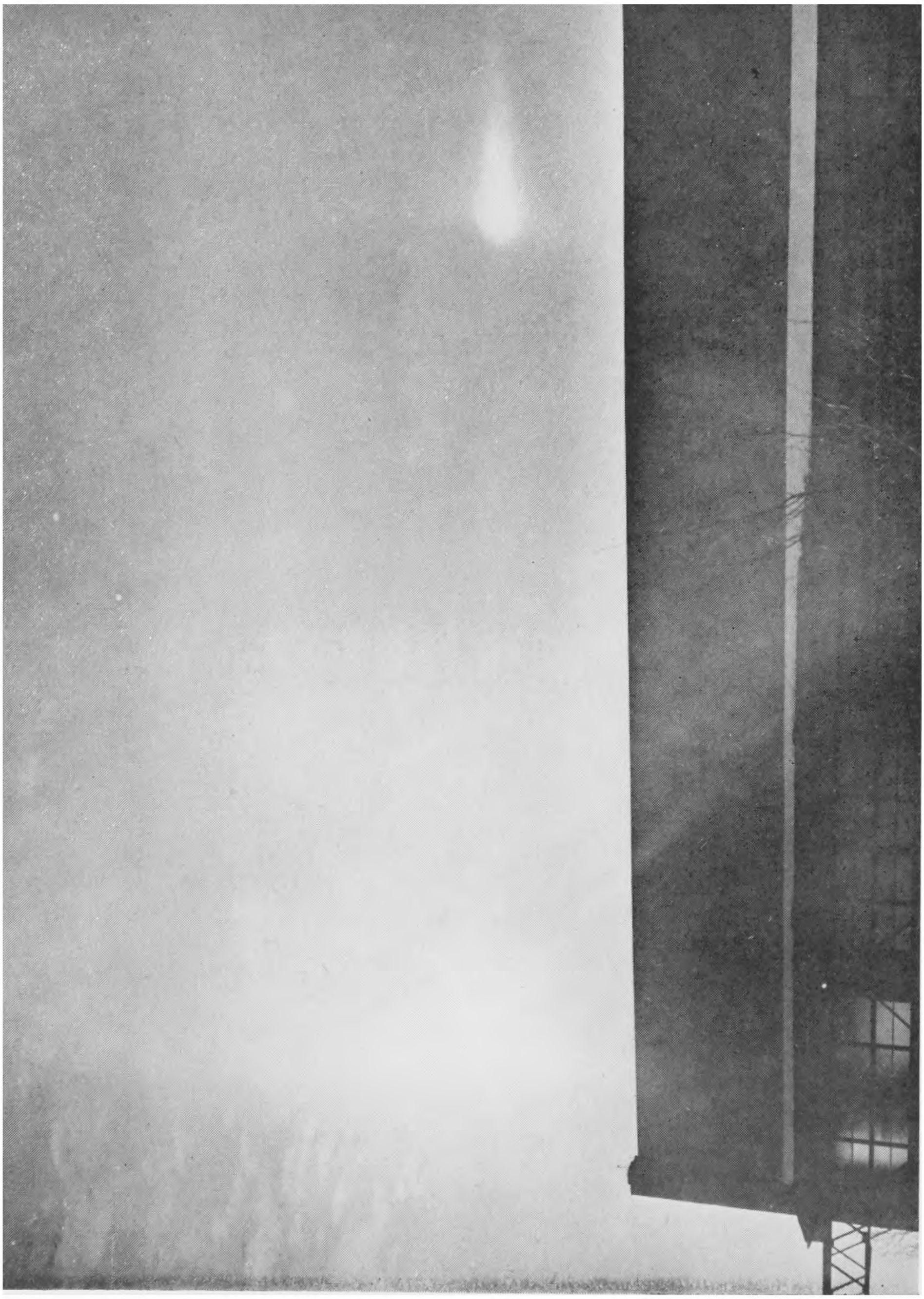
Same cloud one minute later



Same cloud almost fully developed, with typical anvil, five minutes after first photograph

CUMULONIMBUS CLOUD OVER THE ATLANTIC OCEAN

of 10,000 ft. (see p. 120).



MOCK SUN AT WEST RAYNHAM, NORFOLK, 1215 G.M.T., DECEMBER 6, 1950

Dr. Sutcliffe inquired whether this feature of the humidity elements would render the observations valueless in fog. Mr. Best thought this would not be so.

Mr. Marshall drew attention to the difference between vertical gradients of temperature in London and in the country. A comparison between readings taken on the roof of Air Ministry and at Kensington Palace frequently indicates a temperature gradient markedly different from that indicated by measurements at corresponding heights at Rye.

Mr. Sawyer questioned whether the Rye site could be regarded as a typical site. The proximity to the sea might be expected to give results very different from those obtained at inland stations. In fact a brief comparison between the Rye observations on radiation nights with observations from 24 inland stations on the same nights suggested that the Rye observations showed an appreciably lower relative humidity in foggy conditions than did observations made in an orthodox Stevenson screen. Mr. Best said that the number of observations was not yet sufficient to permit definite conclusions about the effect of the sea breeze. With regard to the accuracy of the Rye observations in fog the humidity elements are not perfect, but nor are observations made by orthodox methods.

Mr. Bigg asked if an attempt had been made to correlate temperature and humidity gradient observations with air mass. Mr. Best said not.

Mr. Knighting stressed the volume of data obtained from these observations and the fact that it will be some time before all the information has been extracted from the mass of observational material now made available by the Rye report. Qualitatively the observations raise no new problems in physics but quantitively these data must affect turbulence theory.

Mr. Gold pointed out the difficulty of understanding why the temperature of the air at 15 m. increases during a winter day if the temperature below this level does not decrease with height.

Mr. Gloyne asked whether the nature of the surroundings at Rye would justify applying the results to other terrains. Mr. Pedlow explained that in this connexion too much significance should not be attached to the term Romney Marsh. The ground round the site is not marshy, but on the other hand the vegetation never shrivels for lack of water.

Mr. L. P. Smith asked whether the proximity of the tower had any effect on the observations and Mr. Best agreed that there might be some small effect.

Dr. Robinson wondered what happened to water vapour evaporated from the ground when there is a zero lapse rate of vapour. Unlike heat the water vapour cannot accumulate to any great extent at one height. Replying to the question put by Mr. Gold, Dr. Robinson suggested that the temperature at one particular height could be raised by radiative transfer of heat.

The Director in closing the discussion emphasized the value of a discussion on new data such as had been presented.

METEOROLOGICAL RESEARCH COMMITTEE

The twelfth and thirteenth meetings of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee were held on February 1 and 14, 1951, respectively.

At the first of these meetings, the Chairman's report to the Meteorological Research Committee was discussed, and recommendations were formulated for the revision of Part II of the Research Programme. The Sub-Committee also considered a report on zonal, meridional and other indices by A. G. Forsdyke[1] which concludes that such indices have little, if any, value in forecasting.

The second meeting was devoted to a discussion of meteorological papers. A study of the structure of warm fronts by A. G. Mathewman[2] was received with interest. A paper describing tests of the Rossby formula as applied to the movement of long atmospheric waves at the 500-mb. level by E. J. Sumner[3] was also discussed; it appears that the Rossby formula, so applied, is not a satisfactory forecasting tool. The Sub-Committee also noted papers on high-altitude photographs of clouds and the significance of strong bands of winds (jet streams) as shown by isopleths of mean winds.

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[1] *Met. Res. Pap., London,* No. 591, 1951.

[2] *Met. Res. Pap., London,* No. 597, 1951.

[3] *Met. Res. Pap., London,* No. 605, 1951.

ROYAL METEOROLOGICAL SOCIETY

Dynamical methods in synoptic meteorology

At the meeting of the Society held at 49 Cromwell Road on January 17, 1951, with Sir Robert Watson-Watt, President, in the Chair, there was a discussion on dynamical methods in synoptic meteorology. The opening speakers were Mr. F. H. Bushby, Mr. E. J. Sumner and Dr. R. C. Sutcliffe.

Dr. Sutcliffe set the tone of the discussion and provided a theoretical background. He was only concerned with those dynamical theories which up to now had actually been applied to forecasting problems, and briefly described in simple terms two approaches. First, the Rossby theory in which the atmosphere was treated as an incompressible barotropic fluid, the absolute vorticity being conserved. In such an atmosphere there were no energy sources, and the theory only dealt with the inertial characteristics of the flow. The earth's atmosphere was of course far from barotropic in middle latitudes but Charney had argued that the theory could nevertheless be applied to a mean state, the flow patterns being averaged vertically to give an "equivalent-barotropic" flow corresponding roughly to the actual flow at about 600 mb., the so-called equivalent-barotropic level. Work along these lines was still in progress in America.

His own approach was to deal with the vertical and horizontal distribution of divergence in the atmosphere[1] and related development (vertical motion) to the thermal field. As Sawyer had indicated[2] the two theories were in a sense complementary. An example was shown of the agreement between the computed field of development and the change in the surface pressure field.

Mr. Sumner then described his paper on "The significance of vertical stability in synoptic development"[3], which entailed the addition of a further term to Dr. Sutcliffe's well known equation. This term is equal to $\beta\nabla_p^2\ (\overline{\Gamma_p dp/dt})$ where β is a positive constant for the isobaric layer under consideration, ∇_p^2 is the Laplacian operator $\partial^2/\partial x^2+\partial^2/\partial y^2$, Γ_p is the departure of the actual lapse rate of temperature γ_p, referred to a pressure scale (i.e. $\partial T/\partial p$), from γ_a the wet- or dry-adiabatic lapse rate, whichever applies, and dp/dt is proportional to the vertical velocity relative to a (moving) pressure surface. The bar over the product denotes a mean value taken vertically throughout the layer in question with respect to a logarithmic pressure scale.

The above expression represents the isallobaric divergence effect due to the dynamical (adiabatic) temperature changes associated with an organized field of vertical motion. It opposes the development both of cyclones and anticyclones when the atmosphere is stable. For instability in depth, which could only arise in the case of cyclonic development, the development would proceed very rapidly. The magnitude of the effect was shown to be directly proportional to the stability parameter Γ_p and inversely proportional to the square of the Coriolis parameter and the square of the dimensions of the pressure system. Small systems could hardly be expected to develop at all in a stable atmosphere, especially in low latitudes.

Secondly, Mr. Sumner gave a few results of a test of the Rossby wave formula based on one year's 500-mb. charts, and of an attempt to apply it numerically in short- and medium-range forecasting. Only wave trains comprising at least two troughs separated by a ridge were considered, the individual members being far from sinusoidal in many cases. A correlation of 0·90 (38 cases) was obtained between the actual 24-hour displacements of troughs at 500 mb. and estimates based on the Rossby formula, after certain random errors of drawing and measurement were smoothed out. Also the zonal velocity and wavelength parameters were shown to be important individually. These results only applied to the cool seasons (winter and spring), and provided some hope of being useful in forecasting practice. Further results for the warm seasons were considered to rule out this possibility.

The Rossby equation, modified by the appropriate regression coefficients, was applied to another period, and the results obtained compared with those achieved in routine forecasting (short- and medium-range) at the Central Forecasting Office, Dunstable. However, this comparison indicated that no improvement on the standard of accuracy at present attained in routine forecasting can be expected by an application of the simple Rossby formula. In spite of this Mr. Sumner thought that the equivalent-barotropic theory may give a useful first approximation in certain cases and for a limited time ahead, provided a not too simple model of atmospheric flow was adopted. Numerical integration from observed stream-line patterns in the manner suggested by Charney was one way which might repay the effort.

Mr. Bushby was concerned with the application of numerical methods to normal synoptic practice, and said that, although the time when all the forecaster's prebaratic and prontour charts could be done numerically may be far distant, some progress had been made in recent years.

He described two series of tests which had been made in the Forecasting Research Division on Charney and Eliassen's method[4] for predicting 500-mb. contour maps 24 hours ahead, which showed fairly conclusively that the results obtained were not quite as good as those obtained by conventional methods, although the predictions of the movement of the troughs and ridges at 50°N. were slightly better. Mr. Bushby stressed, however, that more refined methods based on less restrictive assumptions were being developed which might show more promise. Attempts by himself to improve the one-dimensional method of

Charney and Eliassen were still being made; the results so far obtained provided corrections of the right sign but of greater magnitude than was required to make the forecast accurate.

Another recent development was an adaption of Sumner's equation to give a numerical solution by relaxation methods for the mean vertical velocity over a wide area in the 1000–500-mb. layer. The technique was still being improved, and so far only one case had been worked out. For this case the mean vertical ascent in the vicinity of a depression over the British Isles could account for the amount of rainfall which in fact occurred in the area, using Bannon's method[5] for estimating the rainfall.

In the ensuing discussion Dr. Scorer said that a barotropic atmosphere had no energy source and no developments could take place. Results obtained by such assumptions could easily be 50 per cent. out. Dr. Sutcliffe's theory was also " inertial " but had the merit of taking account of divergence and convergence which were important. He considered that Rossby waves were necessarily stationary waves, and that linear extrapolation would give as good results as barotropic formulæ and quadratic extrapolation better. He also mentioned that the idea that the stability of the atmosphere was important was not new in meteorology.

Mr. Galloway asked at what stage the surface pressure came into the argument, and Mr. Pearce questioned the philosophic basis of the " thermal-development " approach.

Dr. Sutcliffe, in reply, expressed considerable doubts as to the applicability of barotropic theory, but admitted to a cautious optimism as regards developmental ideas. He said that surface developments were implicit in the theory. Mr. Sumner said that Cressman[6] had given figures which showed slightly better results for the Rossby formula than linear extrapolation. Moreover, in practice, one often had to deal with newly formed waves with nothing on which to extrapolate. In his opinion Rossby waves could be either moving or stationary; implicit in the theory (and explicitly in some papers) was the assumption that the field of pressure could and would accommodate itself to the prescribed field of motion of the particular model adopted. The movement of waves whose wave-length differed from the stationary wave-length was presumed to be accomplished by such a process of accommodation, the divergence and convergence associated with the pressure changes producing relatively small changes in the vorticity distribution.

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ROYAL METEOROLOGICAL SOCIETY AND INSTITUTE OF ELECTRICAL ENGINEERS

Symposium of papers on electrical meteorological instruments

A joint discussion meeting was held at the Institute of Electrical Engineers, Savoy Place, on January 30, 1951, beginning at 3.0 p.m. The meeting was divided into two parts: in the first part, before tea, with Dr. G. A. J. Sowter in the Chair, the following papers were read:—

Hartley, G. E. W.— The development of electrical anemometers

Mr. Hartley confined his paper to the development of cup anemometers and wind vanes. Early standard anemometers were calibrated to make an electrical contact for each twentieth of a mile run of wind. Later improvements consisted of changing the shape of the cups from hemispherical to conical to reduce over-estimation produced by gustiness, better bearings, introduction of a cam-operated mercury switch, and insertion of a device for ensuring that, at low wind speeds, an electrical contact is only maintained for a short period. Such anemometers are suitable for measuring the wind over short timed periods. They can be made to record automatically by connecting the contact inpulse mechanism to a telephone message-register or similar electromagnetic counter and photographing the count at regular known intervals automatically (this was the basis of a design by E. L. Deacon); or by letting the impulses lift the pen arm of a suitably graduated recorder by equal small amounts, the pen being allowed to drop at short intervals (3 min. in the Bibby recorder), when the chart drum moves on slightly; or by letting the impulses rotate a chart drum along which a pen carriage moves at constant speed, time being measured by automatic time marks at regular intervals. Mr. Hartley then spoke of new developments in cup-generator anemometers and showed a photograph of the latest type. The main difficulty in such an anemometer was the lag in response of the generator at low speeds, although with a recording a.c. voltmeter it was easy to record the wind between 6 and 90 kt.

Mr. Hartley also described electric wind vanes with remote indicators showing wind direction to 8 or 16 points by means of lights. To overcome the difficulty of recording wind changes of direction exceeding 360° it was necessary to use a recorder of the Baxendell type, where the pen has to move over the joint in the paper without catching in it, or to use a cam or system of cams, or to use the familiar Dines twin-pen system which requires considerable torque. The two-cam system required least torque and was in use in a bi-directional wind vane connected by magslip transmitters to the direction recorder.

Rosenbrock, H. H. and Tagg, J. R. — Wind- and gust-measuring instruments developed for a wind-power survey

Mr. Rosenbrock opened his paper by remarking that, for the purpose of siting wind-driven electric generators, it was necessary to know the wind conditions at windy sites which are not typical of most areas, and in particular the effect of gustiness on windmill blades. Mean wind speed was first obtained from a standard Meteorological Office cup anemometer connected either to a photographic recorder, similar to E. L. Deacon's, or later, to an impulse recorder making dots on a moving chart. Gusts, after consideration and rejection of a hot-wire anemometer, bridled-cup anemometer, cup-generator, windmill anemometer, pressure-tube anemometer and plate anemometer, were finally measured by allowing the wind to blow against a perforated aluminium sphere held up by an almost vertical rod pivoted at its middle. The bottom of the rod is attached by a steel wire to a spring diaphragm, the deflexion of which is approximately proportional to V^4 at low speeds and $V^{4/3}$ at high speeds (V=wind velocity). The deflexion was measured by a mechano-electric transducer which takes the form of a miniature triode which is usually operated with the grid connected to the cathode. Mr. Rosenbrock showed a few records of this anemometer, chart speeds of which may vary from ½ in./sec. to 6 in./sec. A 1 in./sec. speed was found sufficient to show all the detail in the records, the faster speeds being used to find the response of the anemometer. The response was complete in about 0·07 sec.

Hawkes, H. D. and Laws, J. M.—An electrical method of resolving true wind velocity aboard ship

A sinusoidal voltage or current can be represented by a simple vector, and, if a number of alternating quantities of the same frequency act at the same time in a given circuit, their resultant is given by their vector sum, just as in the resultant of a number of co-planar velocities. Mr. Hawkes showed how, in the Elliot wind recorder, an electric vector representing apparent wind aboard ship, by means of a resolver, is combined with a similar vector representing the ship's velocity to produce automatically the true wind speed and direction on remote indicators and recorders.

Bell, J. and Langham, E. M.—Mean-wind-velocity instruments for use on naval craft

Mr. Bell described two instruments, both using mechanical computing and transmitting devices, the first to indicate continuously the mean direction of the apparent wind and the second to indicate the true force and direction of the wind, regardless of the speed and direction of the ship, and further to obtain the mean apparent wind force and direction. The instruments are suitable combinations of magslip transmitters and resolvers, induction potentiometers and generators, and servo motors connected together mechanically or electrically. The induction potentiometer has a toroidal winding round a magnetic-core ring so that when a load is taken from a subdividing point the accuracy of the divided voltage can be relied upon to within 0·1 per cent. and the whole winding is still available for other purposes. The remaining devices are rather like generators or motors, except that the rotors and stators do not always have the same phase windings — for instance a magslip transmitter has a single-phase rotor and a three-phase stator, and a servo motor has a three-phase rotor with an external resistor carried on a spindle and a stator with a two-phase winding, one from a mains supply and the other through an electronic amplifier.

The discussion on these four papers was opened by Sir Nelson Johnson, who said that the Meteorological Office would like help from electrical engineers in the design of instruments; he stressed that meteorological requirements included a measure of the lack of uniformity (such as gustiness) — patchiness he would prefer to call it — over the whole scale of phenomena extending down to the small micrometeorological scale in units of millimetres and hundredths of a second and right up to air-mass phenomena in units of 100 Km. and days. This was a range of 10^8.

Sir Nelson was interested in the perforated-sphere anemometer and thought the transducer could be applied in a number of ways; he would like to know the period of response of the anemometer in a gusty wind. Other speakers thought that the hot-wire anemometer had been dismissed too readily. Prof. MacGregor-Morris said that he had tried to produce a portable instrument some forty years ago with wires enclosed in a circular rod and showed a photograph of the instrument in use at Happisburgh Lighthouse in 1912; it was sensitive to low velocities. Another speaker suggested that a frequency type of coupling might be used to reduce friction losses in a recording instrument and mentioned the idea of a toothed wheel being observed through a gap.

Mr. Rosenbrock replied that the perforated-sphere anemometer would measure down to 20 m.p.h. but there was a natural frequency in one part of about $\frac{1}{12}$ sec.; the recorder would not respond in less than $\frac{1}{10}$ sec. for it overshoots. He also said that the hot-wire anemometer needed repeated calibration because of the collection of dust on the wire, and the time of response would be increased if it was enclosed in a tube. In reply to Dr. Scrase, Mr. Bell said that damping of the wind vane had not been used in measuring the mean wind because of the different forces available in a wind of 2 m.p.h. and 60 m.p.h. It had been thought better to use a mechanical governor in the transmission, thus controlling the speed of response.

After tea, Sir Robert Watson-Watt took the Chair and the following papers were read:—

Jones, F. E., Hooper, J. E. N. and Alder, N. L.—The radar-sonde system for the measurement of upper wind and air data

The slant-range obtained in wind measurement by radar with the normal corner reflector is of the order of 30 miles. Much greater ranges can be obtained by using an airborne transmitter. Dr. Jones showed how this has been achieved with a transponder which receives impulses from the ground station in the range 151–154 Mc./sec. and retransmits them in the 2,700–2,900-Mc./sec. region (10·7 cm. wave-length). At the same time it is possible to signal back the readings from the usual meteorological elements. The whole radar-sonde, together with batteries, container, telemetering unit and switches weighs only 4½ lb. of which the batteries account for 3 lb. All except the arials and the temperature and humidity elements are enclosed in a non-conducting onazote container 1 in. thick. Since this is not quite air-tight and the valves generate enough heat in ascent to keep the inside within a few degrees of room temperature at all heights, it is possible to measure pressure inside independently of temperature and also to telemeter information roughly ten times more accurately than with radio-sonde. The switch to bring each element, in turn, into the circuit completes a cycle in 15 sec.—3 sec. for each element and a reference — and is based on a telephone meter. The ground station contains a transmitter, a master calibrator, a receiver, a wind computor, a pulse-code demodulator, and a recorder of pressure, temperature and humidity — all working automatically and including magslip resolvers and electrical pulse counters.

Dr. Jones thought that, with mass production and the saving of some ground personnel, it would be possible to achieve a cheaper upper air sounding than with the present radio-sonde system.

Brewer, A. W. and Dobson, R. H.—An automatic frost-point hygrometer for measurements in the upper air

Dr. Brewer described an effort to make the Dobson-Brewer frost-point hygrometer fully automatic. The cooled thimble is watched by a photo-electric cell which, by a suitable electric circuit, controls additional heating of the thimble (it is normally over-cooled) until the growth of hoar-frost crystals on the thimble is constant and equal to their sublimation. The temperature of the thimble (which is measured by a thermocouple) is then the frost point of the air sampled. Although the apparatus had worked successfully in the laboratory, defects, still unresolved, had been found in aircraft use.

Pratt, A. W., Collins, B. G., Lacy, R. E. and Spink, E. W.—Some meteorological instruments used in building research

Mr. Pratt described meteorological instruments developed at the Building Research Station. The first of these was concerned with measurements of the ventilation rate of buildings; it had been found that in winds below 4 or 5 m.p.h. the rate of ventilation depends on the temperature difference between the outside and inside and at higher speeds on the wind velocity. The wind-run analyser is an electrical circuit operated from the standard Meteorological Office cup anemometer which makes a contact twenty times per mile of wind run. The analyser counts the contact with a system of relays over hourly intervals and records the count on a chart.

The second instrument was the directional wind recorder which consisted of a cup anemometer with contacts, an 8-way switch driven by a wind vane and a set of electromagnetic counters. The signals of the anemometer are distributed by the direction switch to the appropriate counters, and so the device counts the wind run from the 8 directions and also the total run. The contacts are arranged so that each contact of the cup anemometers records through only one directional switch even though the vane swings to another direction during contact.

The third instrument was the equivalent-air-temperature recorder, which is designed to record an air temperature taking into account heat loss or gain by radiation and convection, for calculation of heat flow through walls from the conductivity formula; it is the temperature of the wall when exchanging heat freely with its surroundings and no heat is flowing through it. The instrument is a cube with four vertical graphite receiving surfaces and one horizontal one facing upwards. The temperature of each graphite receiver is recorded by a thermopile arranged to record the difference between the temperature of the surface and the temperature in a screen slung under the apparatus.

The fourth apparatus was developed for the measurement of temperature and the calculation of mean temperature at a number of points inside experimental buildings. The apparatus records the readings of a number of resistance thermometers at 44 separate points and sums 100 readings a week at each point. It is built up of an arrangement of uni-selectors.

In the course of the discussion, Prof. Sheppard referred to the value of instruments such as the radar-sonde to meteorologists, and their appreciation of the designer's difficulties. Dr. Scrase and Dr. Harrison dealt with calibration pointing out that a more costly instrument which did not require individual calibration might well be cheaper in use.

Dr. Harrison also said that a hypsometric method of measuring pressure in the free air was being considered, and that he was not sure of the effectiveness of the radar-sonde container in maintaining constant temperature; Dr. Hopkins asked if there would be site-errors for the radar-sonde; Mr. Humphreys suggested that a continuous-wave radar system might be cheaper for wind measurement than a pulse system; and Mr. D. D. Clark thought the rate of ventilation of the Dobson-Brewer hygrometer was more important than Dr. Brewer had suggested as it made a difference to the rate of growth of crystals.

In reply, Mr. Lacey said that the Building Research Station had considered existing instruments before designing new ones; Dr. Brewer was doubtful about increasing the ventilation of the the frost-point hygrometer at low temperatures because of the amount of heat brought in by the air; Mr. Hooper said the radar-sonde was a compromise between cost and accuracy, that the telemetering circuit was the only part needing calibration and that there was adequate leakage of air through the container.

METEOROLOGICAL OFFICE PUBLICATION

The following publication has recently been issued:—

METEOROLOGICAL REPORTS

No. 8—Upper air analysis and tropical forecasting. By R. A. S. Ratcliffe, B.A.

This report is an attempt to bring out the uses of upper air analysis in relation to tropical forecasting. Attention is focussed mainly on the 1000–500-mb. thickness chart and on the 700-mb. contour chart. The report is based on data available in south-east Asia in 1945.

The characteristic upper air patterns before and during the SW. monsoon periods over India and the adjacent areas are discussed, together with some day-to-day changes in patterns which can be correlated with the weather. Various miscellaneous applications of upper air charts to synoptic forecasting in the tropics are suggested.

NOTES AND NEWS

Condensation trails

The photograph, facing p. 110, of condensation trails and their shadows on a sheet of high altocumulus was taken at the Royal Aircraft Establishment, Farnborough, at 1415 G.M.T. December 20, 1949. The camera was pointing to the west and upwards.

We are indebted to Mr. T. H. Applegate, Meteorological Officer at Farnborough, for drawing attention to this photograph and to the Ministry of Supply for permission to reproduce it.

The interesting question, as Mr. Applegate realized on seeing the photograph, is whether the condensation trails were on the near or far side of the cloud sheet so that their shadows were projected on to the lower or upper surface of the cloud sheet.

The elevation of the sun above the horizon at the time was approximately 10°. From this it follows that the trails were above the cloud unless the cloud sheet was sloping upwards to the south-west at such an angle that its slope in the direction from the trails to the sun exceeded 10°. It seems unlikely that the sheet was sloping at so steep an angle. It is by no means unknown for cloud to be seen through a thin sheet of cloud. The International Cloud Atlas has a photograph, Plate A 22, of cumulus cloud seen through altocumulus translucidus. Condensation trails seem brighter than thin altocumulus particularly when seen by the light from a low sun. A condensation trail was clearly seen through altocumulus from Harrow at 1615 G.M.T. on October 10, 1950, a time when the position of the sun is much the same as at 1415 G.M.T. on December 20.

Development of a cumulonimbus

The four photographs in the centre of this magazine were taken from a height of 10,000 ft. at approximately one minute intervals on July 31, 1943, by the crew of an aircraft from St. Eval when returning from a meteorological reconnaissance flight, in a position 100 miles south-west of Ireland. They show the the development of a rather solitary cloud protruding through a layer of cumulus cloud, the top of the layer cloud being almost 10,000 ft.

OBITUARY

Captain L. A. Brooke Smith, R. D., R.N.R.—Captain L. A. Brooke Smith, Marine Superintendent of the Meteorological Office from 1919 to 1938, died at his home in Suffolk on December 21, 1950, aged 72.

Louis Alfred Brooke Smith, son of a master mariner, was born in Cape Colony and educated in the Colony and in the school ship *Conway*. After apprenticeship and two years Royal Naval Reserve Training he qualified as Extra Master in 1903 and joined the Orient Line. He received rapid promotion and was appointed to command R.M.S. *Omrah* in August 1913. During the war of 1914 to 1918 he rendered distinguished service in the Royal Navy. rising to the rank of Commander, R.N.R.

On demobilization from the Royal Navy in 1919, Commander Brooke Smith was appointed Marine Superintendent of the Meteorological Office, which post had become vacant by the death of Captain Campbell Hepworth, C.B., R.D., R.N.R., Commander Brooke Smith had always been a keen observer for the Meteorological Office, as shown by the meteorological logs received from ships in which he served, and he thus took up his new appointment with a first-hand knowledge of what was required of an observer at sea, and a strong desire to make the work at sea not only of scientific value to the professional meteorologist ashore but of sound practical value to the navigator himself in the daily performance of his duties. He worked unceasingly throughout his tenure of office with this object in view.

All meteorological work at sea had ceased during the four war years so that Commander Brooke Smith, on taking up his new appointment, had to start afresh in obtaining the interest of the shipping community in marine meteorology. Starting at the beginning, he realized that if a high standard of observation was to be maintained in future years, early training would be essential. A Cadet's meteorological log was therefore drawn up, to be kept at the three

Cadet establishments, *Conway*, *Worcester* and *Pangbourne*. By making frequent visits to the larger ports, and giving lectures on the value of marine meteorology to both shipowners and ships' officers, he was most successful in building up a new Observing Fleet and Voluntary Corps of Marine Observers. By his visits to the ports he was also able to obtain a consensus of nautical opinion as to what steps should be taken to provide the mariner with meteorological information that would be of practical assistance in day-to-day navigation. Hitherto, the work at sea had consisted of keeping meteorological log for climatological purposes only, but with the then rapidly growing use of radio at sea it became possible to apply ships' observations to synoptic meteorology. He drew up a scheme whereby ships when within range of coast stations regularly transmitted their reports to WEATHER LONDON for use in the Forecasting Division of the Meteorological Office. A weather bulletin was also broadcast to all shipping on both long and medium waves from a powerful British coast station. This bulletin included reports of weather observed at selected shore stations and by ships in the eastern Atlantic. With such reports at their disposal, ships were encouraged to plot their own simple synoptic charts and to deduce from them the probable change of weather that they were likely to experience as they proceeded on their course during the next twelve hours. Ships were also encouraged to broadcast radio weather messages at regular intervals for the benefit of " All Ships ", in all oceans of the world, so that all in turn could draw a synoptic chart from the data received, and so keep themselves weatherwise. This scheme worked so successfully that an extension of it, known as the " selected ship scheme", was adopted by the International Meteorological Organization and was brought into use by all maritime nations in 1930. To assist the Voluntary Corps of Marine Observers in obtaining the fullest advantage from the "selected ship scheme", Captain Brooke Smith published a book for their use, " Wireless and weather, an aid to navigation".

It had been the practice, for many years, to publish articles of interest on the backs of the old monthly meteorological charts of the oceans, then supplied to all observing ships. With the advances made in meteorology and the keen interest evinced by marine observers in the subject, this means of keeping them informed was no longer considered adequate. A magazine, the *Marine Observer*, devoted to marine meteorology and written chiefly for the benefit of marine observers was brought into being in 1924, a particular feature in each number being a section termed "The marine observers' log", in which were published observations of natural phenomena of every description recorded at sea by individual observers, thus providing a means whereby mariners might pass on their experiences to others.

Another branch of the work which Captain Brooke Smith considered of primary importance was the more exact representation of the set and drift of the surface currents of the oceans, knowing that so many fine ships had been lost because of insufficient knowledge of the vagaries of currents. By interesting marine observers in this matter and encouraging them to forward observations of current, he was able to lay the foundation of the modern method of combining current data statistically and publishing the results in the form of atlases.

The observations recorded in ships' meteorological logbooks were originally extracted by hand into appropriate data books, and with the gradual increase of the Observing Fleet this method was found to be very slow and laborious.

On Commander Brooke Smith's attention being drawn by his scientific officer, Mr. C. S. Durst, to the possibility of using Hollerith machines to extract the data, he was quick to grasp its significance, with the result that the Hollerith method of data extraction was introduced in the Marine Branch in 1921. Without this foresight it would have been impossible to make the computations necessary for the meteorological atlases of all oceans, which were produced, and found so valuable, during the recent war.

Captain Brooke Smith also wrote and published a manual, especially for the use of seamen, entitled " A Handbook of weather, currents and ice", which has been largely used by personnel in the Merchant Navy. A Younger Brother of Trinity House, he was promoted to Captain, Royal Naval Reserve, in 1923. He was also a Founder Member of the Honourable Company of Master Mariners. He retired from the Meteorological Office in December 1938 on reaching the age of 60. During the whole of his 19 years of service as Marine Superintendent he worked unremittingly to achieve the aim which he had so much at heart, to assist seamen to make themselves proficient in the application of meteorology and sea-surface current information in the interests of safe and economical navigation.

Both the Meteorological Office and his brother seamen owe much to the work of one who was himself, first and foremost, a practical seaman, proud of his profession and zealous in advancing its standard of attainment in every way. His passing will be deeply regretted by all who knew him.

J. HENNESSY

WEATHER OF FEBRUARY 1951

Mean pressure was above 1020 mb. over an area covering part of western Canada, the eastern half of the United States, the Azores and part of Morocco. It was below 1000 mb. in an area west of southern Norway which included Iceland and the northern half of the British Isles, and extended nearly to southern Greenland, the mean being lowest (about 994 mb.) to the south-westward of the Faeroes.

It was above the average for February at the Azores, north-westward of the Azores and over the eastern half of the United States, the excess exceeding 10 mb. from Newfoundland eastwards to about 35°W.; there was also an excess around Spitsbergen and between Spitsbergen and the Gulf of Finland. Between the areas of excess there was one of substantial deficit, comprising nearly all the region between Greenland and the north coast of Africa, and exceeding 10 mb. south-westward of the Faeroes, over the British Isles and part of France.

In the British Isles the month was unsettled and rather cold, with frequent snow or sleet showers in some parts, particularly on high ground. It was wet except in the north-west, the rainfall being particularly heavy in the south-east. Conditions were generally unsettled until the last two days.

From the 1st to the 3rd a depression moved north-north-east from the south of Iceland, and troughs of low pressure crossed the British Isles. Rain, sleet or snow occurred and rainfall was moderately heavy in some areas on the 2nd and 3rd. On the 4th an exceptionally deep depression moved across Ireland to the Irish Sea and then turned north-north-west to the south of Iceland. Pressure fell to 942·3 mb. at 1500 at Cork, a value which is probably very near to the minimum sea-level pressure attained in this depression, and is the lowest ever recorded in the British Isles in February. The readings of 951·7 mb. and 961·2 mb. at Ross-on-Wye and Kew Observatory respectively were the lowest in February during their long records. Widespread severe gales occurred in the British Isles on the 4th and 5th and precipitation was heavy on the 4th; 2·35 in. was recorded at Glen Tanar on Deeside. Showery weather, with long sunny periods locally, prevailed on the 5th and 6th. On the 7th another depression west of Ireland moved east and later north-east, followed by a secondary disturbance on the 8th off the south-west coast moving east-north-east. Precipitation on the 8th was heavy locally in the south of England. From the 10th to the 15th a depression situated initially off Brittany moved a little south and troughs or secondary depressions moved north-north-west or north from the south of France. Rain, sleet or snow occurred at times and thunder was recorded locally on the 12th and 15th. A trough off the south-west coast which followed caused considerable rain and local thunder. On the 16th a depression developed off north-west Ireland which then moved north-east and deepened, while on the 17th a wave depression approached the mouth of the English Channel and moved quickly east-north-east. Gales were recorded in the west and north and precipitation was heavy in some areas; 2·65 in. was recorded at Dundonnell House in north-west Ross-shire, and 2·45 in. at Kinlochquoich in Inverness-shire; snow blizzards swept the counties of Perth, Inverness and Argyll. Showers and local thunderstorms occurred on the 18th and 19th followed by moderately heavy rainfall in the south of England on the 20th caused by a small secondary depression moving quickly east-north-east. A complex area of low pressure to the west and north-west of the British Isles then moved east to the North Sea and showery weather prevailed, with long sunny periods. Showers also occurred on the 23rd and 24th associated with a small depression off the north-west coasts moving south-east in the northerly air stream, and on the 25th and 26th a trough of low pressure moving south-east across the country caused further precipitation. In the rear of this trough a ridge of high pressure built up over the British Isles and moved south; the closing days of the month were mainly fair apart from local fog. This was the fourth consecutive month with mean temperatures below the average. The lowest screen minimum temperatures included 20°F. at Kielder Castle on the 21st, 15°F. at Dalwhinnie on the 3rd and 24°F. at Aldergrove on the 10th and Ballykelly on the 15th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	55	20	−0·9	186	+5	96
Scotland	54	15	−2·1	103	+3	96
Northern Ireland ...	53	24	−3·3	113	+3	120

RAINFALL OF FEBRUARY 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	5·04	302	*Glam.*	Cardiff, Penylan ...	4·49	153
Kent	Folkestone, Cherry Gdn.	5·72	282	*Pemb.*	Tenby	3·99	138
,,	Edenbridge, Falconhurst	7·20	326	*Card.*	Aberystwyth	1·68	68
Sussex	Compton, Compton Ho.	6·68	253	*Radnor*	Tyrmynydd	7·54	144
,,	Worthing, Beach Ho. Pk.	5·49	277	*Mont.*	Lake Vyrnwy	7·80	171
Hants.	Ventnor, Roy. Nat. Hos.	6·97	332	*Mer.*	Blaenau Festiniog ...	8·93	109
,,	Bournemouth	6·04	253	*Carn.*	Llandudno	3·35	172
,,	Sherborne St. John ...	6·21	284	*Angl.*	Llanerchymedd ...	4·41	174
Herts.	Royston, Therfield Rec.	3·75	244	*I. Man*	Douglas, Borough Cem.	3·08	97
Bucks.	Slough, Upton	5·03	296	*Wigtown*	Port William, Monreith	2·65	86
Oxford	Oxford, Radcliffe ...	3·45	210	*Dumf.*	Dumfries, Crichton R.I.	3·29	101
N'hants.	Wellingboro' Swanspool	3·25	202	,,	Eskdalemuir Obsy. ...	4·61	93
Essex	Shoeburyness	4·14	337	*Roxb.*	Kelso, Floors	2·02	119
,,	Dovercourt	3·73	294	*Peebles*	Stobo Castle	3·53	128
Suffolk	Lowestoft Sec. School ...	2·85	203	*Berwick*	Marchmont House ...	2·08	100
,,	Bury St. Ed., Westley H.	3·32	221	*E. Loth.*	North Berwick Res. ...	1·93	124
Norfolk	Sandringham Ho. Gdns.	2·37	144	*Midl'n.*	Edinburgh, Blackf'd. H.	1·93	116
Wilts.	Bishops Cannings ...	4·76	225	*Lanark*	Hamilton W. W., T'nhill	2·35	81
Dorset	Creech Grange... ...	7·27	254	*Ayr*	Colmonell, Knockdolian	3·36	87
,,	Beaminster, East St. ...	6·04	200	,,	Glen Afton, Ayr San. ...	4·50	102
Devon	Teignmouth, Den Gdns.	5·87	221	*Bute*	Rothesay, Ardencraig ...	2·76	69
,,	Cullompton	5·05	181	*Argyll*	Morvern (Drimnin) ...	5·15	97
,,	Ilfracombe	4·71	170	,,	Poltalloch	3·56	83
,,	Okehampton Uplands	7·70	176	,,	Inveraray Castle ...	5·56	82
Cornwall	Bude, School House ...	3·70	148	,,	Islay, Eallabus	3·78	90
,,	Penzance, Morrab Gdns.	5·64	169	,,	Tiree	4·01	117
,,	St. Austell	5·36	140	*Kinross*	Loch Leven Sluice ...	3·14	111
,,	Scilly, Tresco Abbey ...	4·40	158	*Fife*	Leuchars Airfield ...	2·61	149
Glos.	Cirencester	4·03	178	*Perth*	Loch Dhu	5·13	69
Salop.	Church Stretton ...	3·92	168	,,	Crieff, Strathearn Hyd.	3·66	104
,,	Shrewsbury	2·02	129	,,	Pitlochry, Fincastle ...	2·97	101
Worcs.	Malvern, Free Library	3·29	183	*Angus*	Montrose, Sunnyside ...	2·52	137
Warwick	Birmingham, Edgbaston	3·11	184	*Aberd.*	Braemar	4·82	169
Leics.	Thornton Reservoir ...	2·87	172	,,	Dyce, Craibstone ...	3·91	171
Lincs.	Boston, Skirbeck ...	3·08	211	,,	Fyvie Castle	3·74	167
,,	Skegness, Marine Gdns.	3·30	216	*Moray*	Gordon Castle	3·49	182
Notts.	Mansfield, Carr Bank ...	3·67	200	*Nairn*	Nairn, Achareidh ...	1·92	119
Derby	Buxton, Terrace Slopes	5·82	155	*Inverness*	Loch Ness, Garthbeg ...	2·75	80
Ches.	Bidston Observatory ...	2·19	130	,,	Glenquoich	6·59	64
Lancs.	Manchester, Whit. Park	2.12	110	,,	Fort William, Teviot ...	5·02	67
,,	Stonyhurst College ...	3·82	114	,,	Skye, Duntuilm ...	3·64	79
,,	Squires Gate	2·54	120	*R. & C.*	Tain, Tarlogie House ...	1·64	72
Yorks.	Wakefield, Clarence Pk.	2·77	162	,,	Inverbroom, Glackour...	5·69	112
,,	Hull, Pearson Park ...	2·42	146	,,	Applecross Gardens ...	4·60	91
,,	Felixkirk, Mt. St. John...	4·47	146	,,	Achnashellach	5·55	81
,,	York Museum	2·16	143	,,	Stornoway Airfield ...	3·09	73
,,	Scarborough	2·27	135	*Suth.*	Loch More, Achfary ...	5·83	88
,,	Middlesbrough... ...	1·85	142	*Caith.*	Wick Airfield	3·47	153
,,	Baldersdale, Hury Res.	3·32	110	*Shetland*	Lerwick Observatory ...	5·66	179
Norl'd.	Newcastle, Leazes Pk....	2·11	138	*Ferm.*	Crom Castle	3·46	118
,,	Bellingham, High Green	2·86	113	*Armagh*	Armagh Observatory ...	3·02	136
,,	Lilburn Tower Gdns. ...	2·84	143	*Down*	Seaforde	4·23	139
Cumb.	Geltsdale	2·45	94	*Antrim*	Aldergrove Airfield ...	2·02	84
,,	Keswick, High Hill ...	5·56	113	,,	Ballymena, Harryville...	2·76	85
,,	Ravenglass, The Grove	4·65	151	*L'derry*	Garvagh, Moneydig ...	3·66	117
Mon.	Abergavenny, Larchfield	6·53	205	,,	Londonderry, Creggan	3·47	109
Glam.	Ystalyfera, Wern House	6·41	125	*Tyrone*	Omagh, Edenfel ...	3·36	113

M.O. 548 AIR MINISTRY

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UPPER AIR OVER THE FALKLAND ISLANDS

By R. GRAY and N. CARRUTHERS, B.Sc.*

Introduction.—This article is a preliminary survey of the upper air over the Falkland Islands; it is based upon observations by radio-sonde at Port Stanley (51°42′S., 57°51′W., 159 ft. above M.S.L.) taken during the period February 1948 to May 1950. The radio-sonde data from Port Stanley are received month by month in the Meteorological Office where they are punched on Hollerith cards; and Hollerith equipment was used for the initial sorting and tabulations of the survey.

Table I shows the number of observations available at the levels: 900 mb. (about 3,000 ft.), 200 mb. (40,000 ft.) and 60 mb. (60,000 ft.). The data used refer to 1500 G.M.T. Observations at other hours were few, and have been omitted as they were not evenly distributed through the year and would have introduced an undesirable bias in the results. No data were received for August 1948, and so results for August are based on one year's observations only.

TABLE I—NUMBER OF OBSERVATIONS OF TEMPERATURE AND WIND OVER PORT STANLEY

Time of observation: 1500 G.M.T. Period: February 1948–May 1950

	900 mb.		200 mb.		60 mb.	
	Temperature	Wind	Temperature	Wind	Temperature	Wind
			number of observations			
Jan.	31	11	27	0	3	0
Feb.	34	30	28	5	5	0
Mar.	32	43	30	6	7	1
Apr.	38	39	34	6	5	0
May	58	42	52	16	7	1
June	33	27	27	11	3	1
July	28	28	23	11	1	0
Aug.	15	19	14	7	0	0
Sept.	31	22	23	11	0	0
Oct.	22	26	22	6	4	1
Nov.	30	28	27	2	1	0
Dec.	35	16	29	4	2	0
Year	387	331	336	85	38	4

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*The original report, of which this article by Miss. N. Carruthers is a summary, was prepared by Mr. R. Gray of Aberdeen University when he was working in the Upper Air Climatological Section of the Meteorological Office in the summer of 1950.

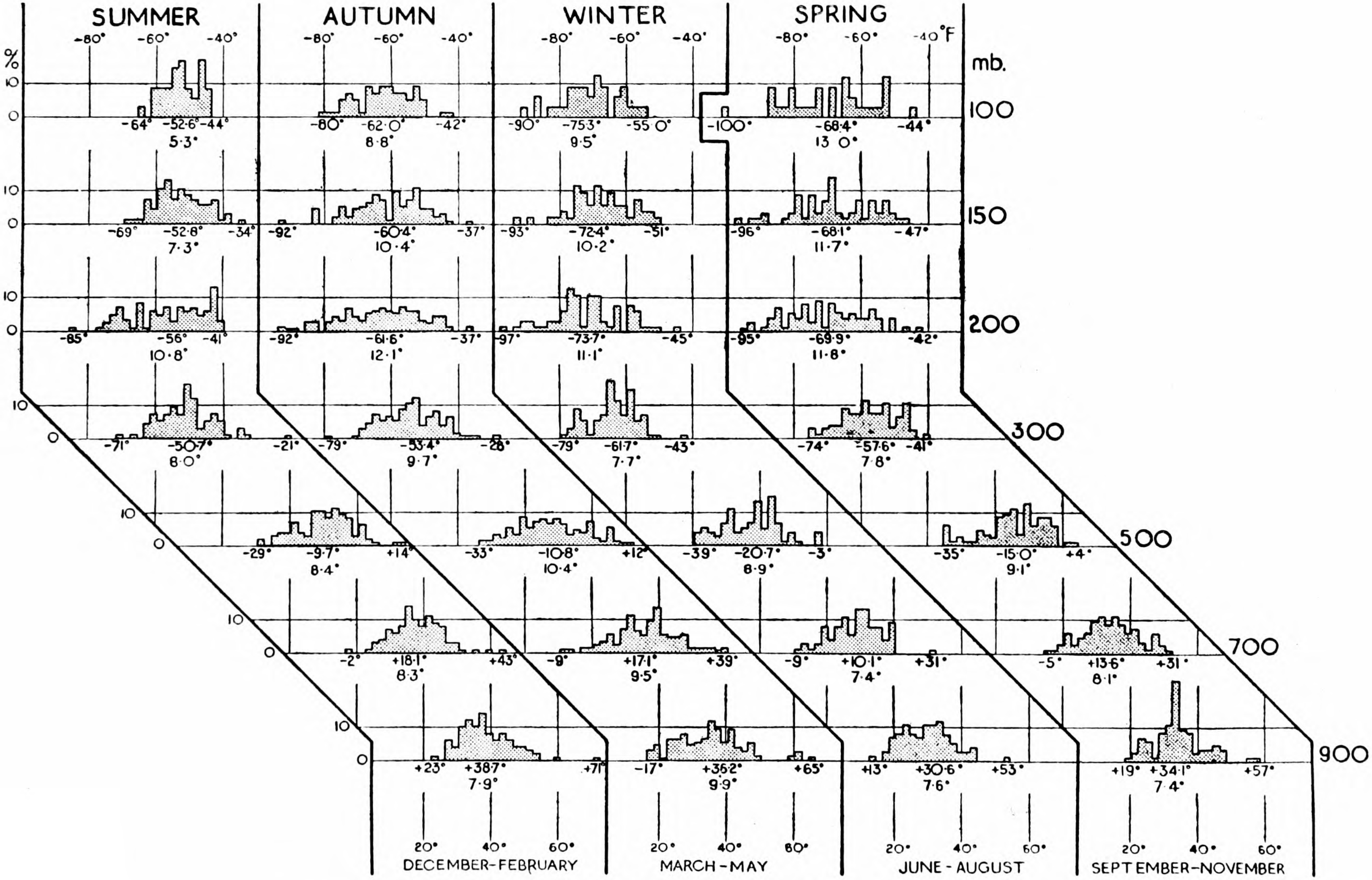

FIG. I—UPPER AIR TEMPERATURES OVER PORT STANLEY

Percentage frequencies of ranges of 2°F. at 1500 G.M.T., February 1948 to May 1950

The values below each histogram are:— { Minimum Average Maximum / Standard deviation } expressed in degrees Fahrenheit

Erratum:—Minimum temperature at 900 mb., March-May should be +17°F. not −17°F.

The data are presented under three main headings: temperature, wind, tropopause. No analysis of humidity has been attempted.

Temperature.—Fig. 1 gives the percentage frequencies of temperature in steps of 2°F. for the four seasons, summer (December to February), autumn (March to May), winter (June to August) and spring (September to November), at the isobaric levels: 900, 700, 500, 300, 200, 150 and 100 mb. The histograms for 850 and 800 mb. (not reproduced here) are very similar to those at 700 mb., but with a general shift to the right associated with slightly higher average temperature. The figures given below each histogram show in the centre the average seasonal temperature at the specified level with the standard deviation of the individual observations below it, and on either side the extremes.

These data give an indication of the annual variation of average temperature as well as showing the absolute range in each season. Neither annual variation nor the absolute range in each season shows much change with height up to the 300-mb. level, but in both there are sudden increases at 200 mb. Decreases, in some seasons, above this level may be due to decreases in numbers of observations. The standard deviation varies with height in a similar manner in each season except that a secondary maximum tends to occur at 500 mb. in winter and spring. This has been found also in the northern hemisphere: at Larkhill, Salisbury Plain (51°12'N., 1°48'W.) and at Juneau, Alaska (58°22'N., 134° 35'W.) there is, in January, a maximum at 500 mb. and a very distinct minimum in the neighbourhood of 300 mb., above which the standard deviation increases to another maximum between 200 and 150 mb.

Fig. 2 shows the variation with height of absolute extremes and of average temperature, the latter being plotted for the midwinter and midsummer months.

It is not possible to assess the diurnal variation of upper air temperature from the data available.

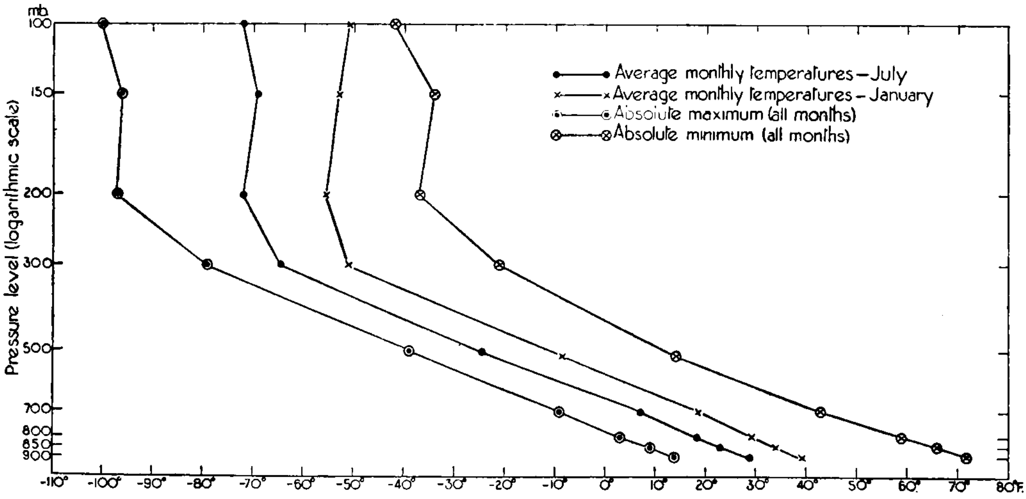

FIG. 2—VARIATION WITH HEIGHT OF UPPER TEMPERATURE OVER PORT STANLEY

Time of observations: 1500 G.M.T., February 1948–May 1950

Wind.—The upper wind data are summarized in Fig. 3. This gives seasonal wind roses at standard levels from 900 to 150 mb. with the corresponding average speed in knots to the right of each wind rose.

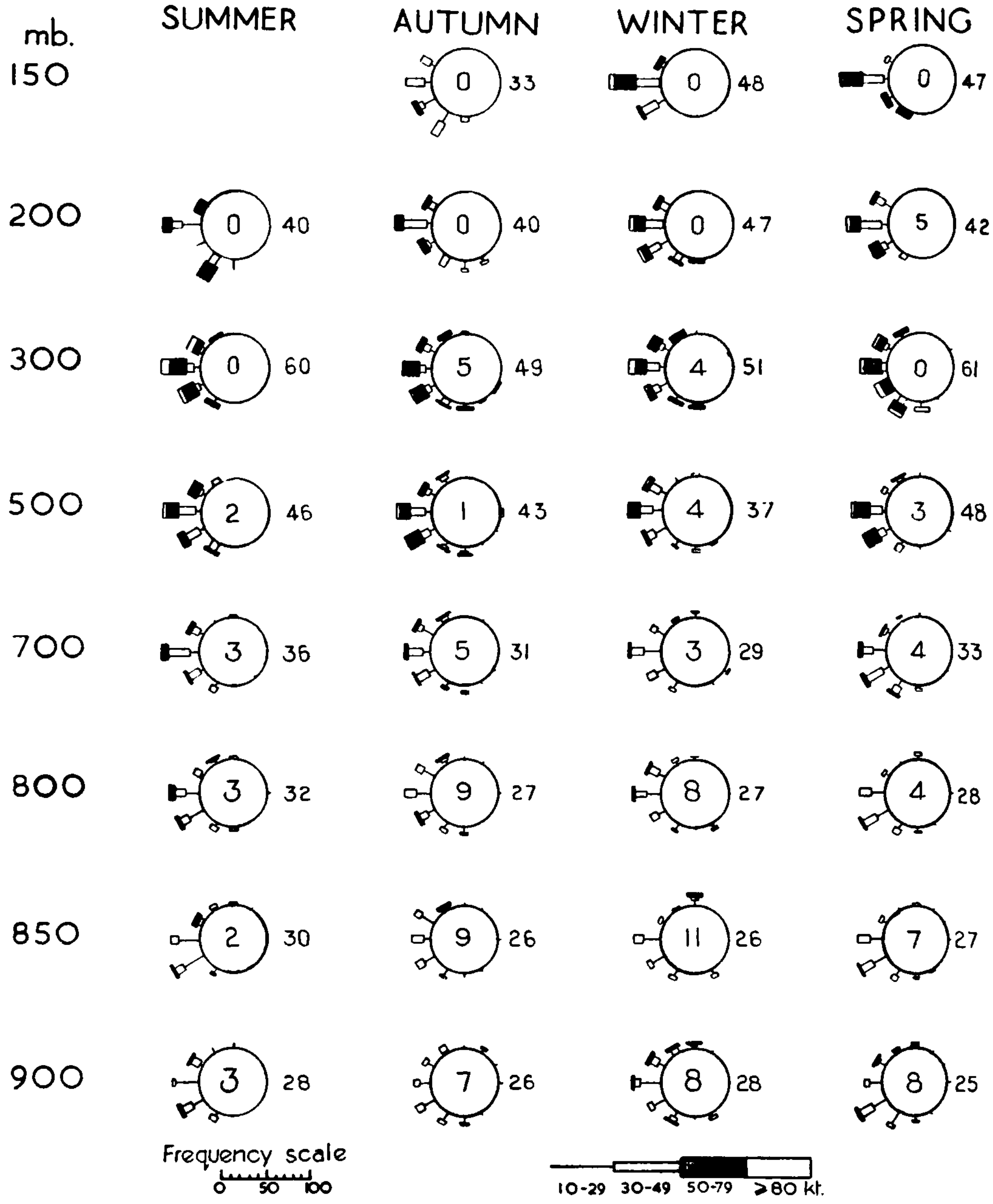

FIG. 3—UPPER WIND ROSES AT PORT STANLEY

The figures within the station circles give the percentage frequencies of wind speeds below 10 kt. Figures to the right of each wind rose give the average speed in knots.

Wind speeds increase with height up to 300 mb. Above this level speeds appear to fall off; but this effect may arise from loss of observations at high levels. The dominant direction in all seasons is westerly, except that in spring SW. winds predominate at levels up to 700 mb.

Tropopause.—Table II gives percentage frequencies of pressure at the tropopause over Port Stanley. These frequencies have been computed for the four seasons irrespective of the temperature and type of the tropopause. The relatively large scatter in autumn probably arises from the larger number of observations, three years' data being available only for this season. Similarly, paucity of observations may be responsible for the relatively small scatter in winter. The values of average pressure, given at the foot of the table, show that the tropopause tends to be lower in summer and winter than in autumn and spring, but the difference is less than twice its standard error. The standard error of each average was computed from the formula,

$$\text{Standard error} = \sqrt{\left(\frac{\text{Variance}}{N/3}\right)}$$

TABLE II—SEASONAL FREQUENCY OF PRESSURE, AVERAGE PRESSURE AND TEMPERATURE AT THE TROPOPAUSE OVER PORT STANLEY

Range	Summer (Dec.–Feb.)	Autumn (Mar.–May)	Winter (June–Aug.)	Spring (Sept.–Nov.)	Year
mb.		*percentage frequency*			
130–9	...	1	...	...	<0·5
140–9	...	...	...	...	...
150–9	...	...	...	...	...
160–9	...	3	...	...	1
170–9	2	2	3	5	3
180–9	2	4	...	5	3
190–9	3	3	...	6	3
200–9	5	5	10	9	7
210–9	6	4	7	8	6
220–9	7	14	9	8	10
230–9	6	7	12	15	10
240–9	16	8	9	3	9
250–9	4	13	6	4	7
260–9	11	7	3	12	9
270–9	6	3	6	8	5
280–9	3	6	2	6	4
290–9	8	6	7	1	6
300–9	2	2	7	5	4
310–9	5	2	6	3	4
320–9	6	2	...	...	2
330–9	3	2	2	...	2
340–9	1	2	4	1	2
350–9	...	1	3	...	1
360–9	2	1	3	...	1
370–9	...	...	...	...	...
380–9	1	1	1	1	1
390–9	...	...	...	...	...
400–9	...	...	...	...	...
410–9	1	...	...	...	<0·5
420–9	...	1	...	...	<0·5
		millibars			
Average pressure	263	249	261	240	254
Standard error	9·0	7·8	10·5	8·4	4·4
		degrees Fahrenheit			
Average temperature	−64	−68	−76	−73	−70
Number of observations	88	121	68	76	353

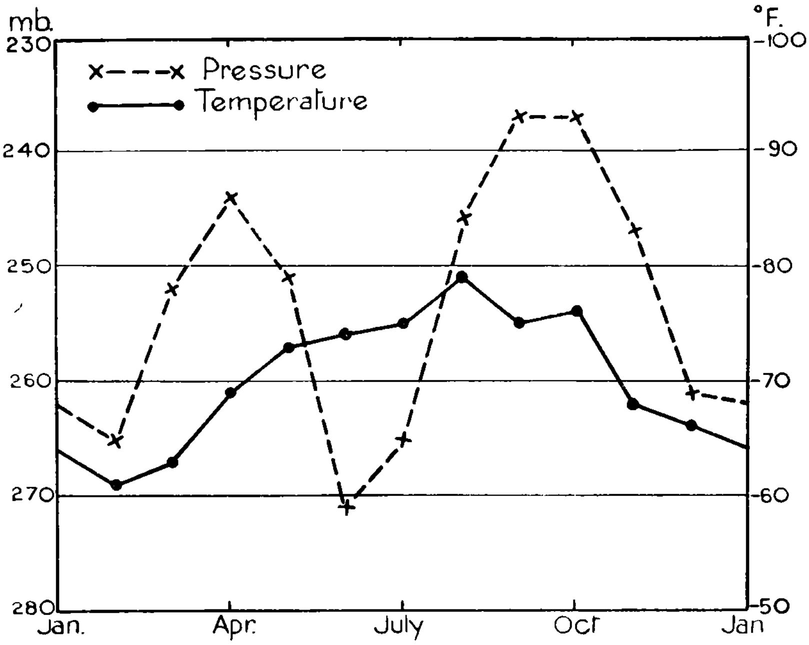

FIG. 4—AVERAGE MONTHLY PRESSURE AND TEMPERATURE AT THE TROPOPAUSE OVER PORT STANLEY

where *N* is the number of days for which observations are available. The factor 3 is introduced to allow for " persistence " from one day to the next.

Average temperatures also, for the four seasons, are given in Table II; and the average monthly values of pressure and temperature at the tropopause are plotted in Fig. 4. It will be seen that winter average temperatures were low in spite of the low level of the tropopause in June and July. An examination of mean values of tropopause pressure in individual years suggests that the semi-annual oscillation, shown in Fig. 4, may be peculiar to the particular two-and-a-half years under survey.

A high positive correlation was seen to exist between pressure and temperature at the tropopause, comparable with that found by C. H. B. Priestley[1]. Priestley gives correlation coefficients of +0·75, between temperature and pressure at the tropopause, and —0·47 between temperature and height. The latter shows rather less correlation than the value of —0·68 given by W. H. Dines[2].

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2. DINES, W. H.; The characteristics of the free atmosphere. *Geophys. Mem., London,* **2**, No.13, 1919.

UNUSUAL DEEPENING OF A FRONTAL DEPRESSION OVER THE BRITISH ISLES

By E. J. SUMNER, B.A.

The purpose of this article is to give a factual account together with a theoretical discussion of a depression which deepened over the British Isles on October 24–25, 1945. But, before doing so, it is necessary to present as briefly as possible the theoretical ideas on which the study is based.

Theoretical background.—The following treatment is based on a theory of development in relation to the thermal field by Sutcliffe[1]. In this theory Sutcliffe assumed that some of the essential features of the formation of pressure systems could be explained in terms of a relatively simple convergence-divergence model. The " development ", as measured by the relative divergence (i.e. the vertical motion) between two given pressure levels p and p_0 ($p_0 > p$), is given by the equation:—

$$l\,(\mathrm{div}_p\mathbf{V} - \mathrm{div}_p\mathbf{V}_0) = -\,V'\frac{\partial}{\partial s}(l + 2\zeta_0 + \zeta') \qquad \ldots (1)$$

in which $\mathbf{V}$ is the horizontal wind vector, $\mathrm{div}_p\mathbf{V}$ the isobaric divergence, ζ the vorticity at the pressure level p (suffix o refers to the lower level p_0), V' is the magnitude of the wind shear (the thermal wind) between p and p_0, $\partial/\partial s$ denotes differentiation in the direction of shear, ζ' is the thermal vorticity and l is the Coriolis parameter.

The relative divergence must be positive for cyclonic development (ascent), and negative for anticyclonic development (subsidence). The expression on the right of equation (1) may be considered as three separate terms, the first of which is small as is the second in the early stages of the formation; in any case the second is mainly concerned with the steering of the disturbance. The third term, $-\,V'\partial\zeta'/\partial s$, the so-called thermal vorticity effect, is the primary development factor.

The reader is referred to the original paper[1] for a full discussion of the simplifying assumptions on which this equation depends, but one consideration is relevant here, namely, that the flow was treated as quasi-horizontal throughout. In particular, only the modifications of the thermal pattern due to horizontal advection were considered, and the simultaneous changes due to the vertical motion which necessarily accompanies the development were explicitly omitted. Although vertical velocities in the atmosphere are small compared with horizontal wind speeds, they exercise a disproportionate effect (depending on the departure of the vertical temperature lapse from neutral stability) on the thermal field by virtue of adiabatic temperature changes, which react directly or indirectly on the entire field of development.

The above equation may be extended to include this effect by the addition of a further term[2], and becomes:—

$$l\,(\mathrm{div}_p\mathbf{V} - \mathrm{div}_p\mathbf{V}_0) = -\,V'\frac{\partial}{\partial s}(l + 2\zeta_0 + \zeta') + \alpha\,\nabla_p^2\,(\overline{\Gamma w'}) \qquad \ldots (2)$$

In this last expression α is a positive constant for the particular layer of the atmosphere under consideration, Γ is the departure of the actual temperature lapse rate γ from the wet or dry adiabatic γ_a, whichever applies, and is negative for instability and positive for stability, while w' is the vertical velocity relative to (moving) isobaric surfaces. The bar placed over the product $\Gamma w'$ implies an average taken vertically throughout the layer with respect to a logarithmic pressure scale; ∇_p^2 is the Laplacian operator, $\partial^2/\partial x^2 + \partial^2/\partial y^2$, and l is the Coriolis parameter.

The function $(\alpha/l)\,\nabla_p^2\,(\overline{\Gamma w'})$ represents the isallobaric divergence associated with the dynamical temperature changes in an air column. Its contribution to the relative divergence depends on the stability of the atmosphere and the field of vertical motion in the sense that stability opposes both cyclonic and anticyclonic development and instability promotes it. The effect may therefore be called the "field-stability" effect; in practice horizontal variations in the stability parameter may also be of great importance especially in the case of cyclogenesis when frontal discontinuities and sudden transitions from clear to cloud-laden air are likely to occur. However, we here limit ourselves to a consideration of fairly uniform conditions in order to give an indication of the physical nature and the relative magnitude of the effect in question.

A more quantitative assessment may be made on the assumption that the field of $\overline{w'}$ is symmetrical, and has a maximum near to the centre of the pressure system falling sinusoidally to zero on a circle radius R, which we may identify with the size of the system, i.e. $w' = A \cos(\pi x/2R) \cos(\pi y/2R)$, x and y being rectangular co-ordinates; A is positive for ascending motion and negative for subsidence. Ignoring variations in Γ, the field-stability term has an absolute maximum at the centre ($x=0$, $y=0$) of $(\pi^2 \alpha A \Gamma)/(2lR^2)$. For vertical ascent the sign of this expression is positive for instability (Γ negative) and negative for stability, the signs being reversed for subsidence. Thus atmospheric stability damps and instability promotes both cyclonic and anticyclonic development. The magnitude of the effect is inversely proportional to the area of the system, other things being equal, and it may be shown[2] that for systems of radius 400 Km. or more it makes a negligible contribution to the relative divergence; but for smaller systems and for average values of the stability parameter the effect can be of dominating importance.

Subsidence is almost invariably associated with atmospheric stability (super dry-adiabatic lapse rates in deep layers are virtually unknown in the free atmosphere) and the formation of small dynamic anticyclones is more or less impossible owing to strong stability damping. The only possibility of instability in depth arises when the air is saturated and the criterion of neutral stability is the saturated-adiabatic lapse rate. Such conditions are, however, seldom found — turbulent mixing would soon destroy them if they were; the rare circumstances in which they could occur are most likely to be effected by the lifting of a convectively unstable air mass in association with a particular cyclogenesis. In most extratropical cyclones the warm air involved in the ascent is stable, except in shallow layers, and the field-stability effect acts as a damping factor which opposes the primary term. As neutral stability is approached the brake is progressively released, and for actual instability the effect becomes a positive developmental factor. In such circumstances the development is likely to be extremely rapid and the vertical ascent to reach extreme values.

But, even so, there are several reasons why the ascent should not be too excessive or too prolonged. In the first place, the amount of precipitation would be increased and the work necessary to combat the downward drag of the descending raindrops would be derived, at least in part, from the extra latent energy released. In effect, the threshold of instability is not reached until a lapse rate rather in excess of the saturated-adiabatic is attained[3]. Secondly, the effect of the vertical motion itself is to stabilize the atmosphere in the layer for which the vertical velocity is increasing with height (i.e. up to the level of non-divergence), and to increase the instability above in regions where it is decreasing. One would therefore expect the greatest vertical velocities to extend rapidly upwards until the stratosphere is reached, with increasing stabilization below, the whole process being accomplished in the space of a few hours. In practice the occlusion process brings in a different and probably more stable air mass below the frontal surfaces, and, when the deepening is marked by decreasing the depth of the " active " warm air between the surfaces and the tropopause (which may also be descending), quickly limits the scope of the eviction mechanism.

The possible effect of instability has been discussed at rather greater length because there is some suggestion, as we shall see, that such was the case in the depression studied. It should perhaps be pointed out that equation (2) is of doubtful validity and must be used with caution when vertical velocity components are particularly large, since it is based on frictionless, quasi-geostrophic, quasi-horizontal motion (except for the effect of the vertical motion on the thermal field), although both terms must make some contribution.

Description.—Figs. 1–4 illustrate the events of the period as they appeared on synoptic charts. The surface isobars and the frontal analyses were accepted as given in the *Daily Weather Reports*, and the 1000–500-mb. thickness lines were obtained by back-gridding from the 500-mb. contour charts (i.e. subtracting the 1000-mb. contours) drawn in the Forecasting Division, Dunstable. No alterations were made to the patterns at all, and, in fact, the lines obtained fitted the observed 1000–500-mb. thickness values almost exactly, with few exceptions. There is, however, some doubt about the drawing of the isobars over the Atlantic in the early stages (Fig. 1) owing to the scarcity of observations.

The depression originally formed at the tip of a warm sector, which had previously broken away from a deep low over Hudson Bay on October 21, 1945, and which went through its life-cycle fairly quickly as a simple wave depression with a wide warm sector, but earlier, while within the American observational network, a secondary cold front had been present. The wave continued to move steadily across the Atlantic round an almost stationary low south-west of Iceland, deepening slowly and occluding, and was approaching Ireland at 1800 G.M.T. on the 23rd. A secondary cold front was re-introduced on this chart (Fig. 1), which, together with the occlusion ahead of it, constituted a pseudo warm sector. Owing to the paucity of observations there was some doubt both as to the position and depth of the centre (it was drawn with a central pressure of about 985 mb.) and, on the midnight chart (Fig. 2), the centre came over Ireland rather further south than would have been expected from the 1800 chart. Its central pressure was then 981 mb. and it seemed to have formed on the secondary cold front and to have detached itself from the occlusion. By 0300 on the 24th the main centre (979 mb.) was moving slowly over southern Ireland but a new centre was forming further north (the pressure tendency at Aldergrove was $-7{\cdot}4$ mb./3 hr.) and by 0600 the centre had been quickly transferred to north-east Ireland (Fig. 3). The central pressure fell to 971 mb., an 8-mb. fall in three hours, which represents an unusually rapid rate of deepening for middle latitudes (the tendency at Aldergrove was now $-9{\cdot}8$ mb./3 hr.).

The depression became very slow-moving after 0600, drifting north-east to Leuchars by 1800, the central pressure then being 968 mb. (Fig. 4). A further low which deepened in our Atlantic approaches later on the 24th and early on the 25th moved rapidly in, and by 1800 on the 25th had amalgamated with its predecessor. The lowest pressure (964 mb.) was recorded at this time when the centre was slowly moving east over north Scotland.

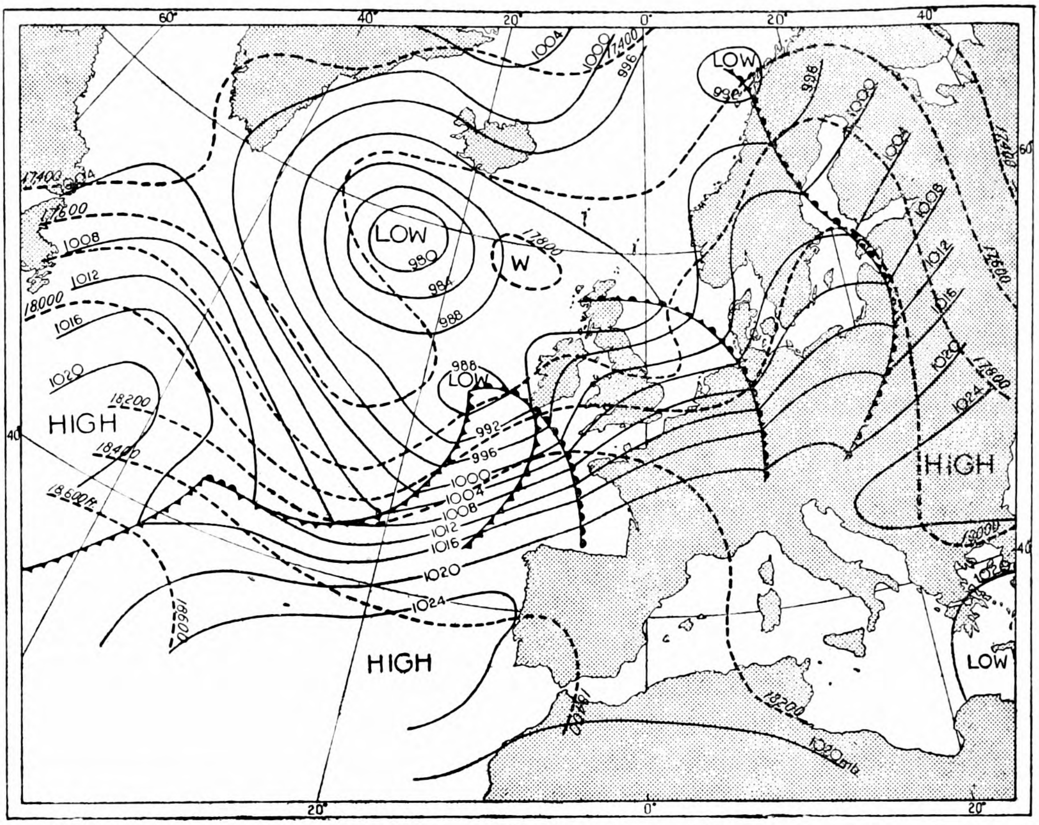
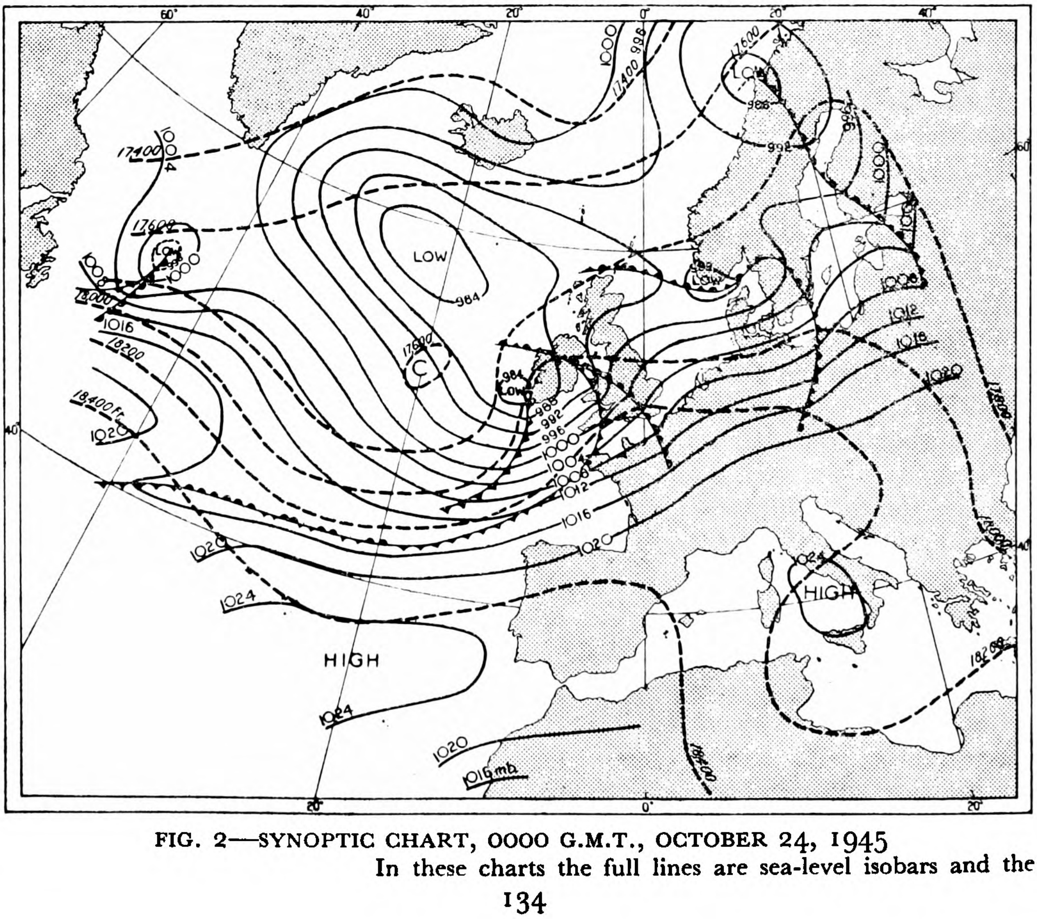

60°
40°
20°
0°
20°
40°
LOW
992
996
1000
17400
1004
17400
17600
1008
1012
18000
1016
1020
HIGH
18200
18400
18600 ft
LOW
980
984
988
W
17800
988
LOW
992
996
1000
1004
1008
1012
1016
1020
1024
HIGH
18600
18400
996
1000
1004
1008
1012
1016
1020
1024
17400
17800
17600
HIGH
18000
LOW
18200
1020 mb
60
40
40
20°
0°
20°

FIG. I—SYNOPTIC CHART, 1800 G.M.T., OCTOBER 23, 1945


60°
40°
20°
0°
20°
40°
1000
996
17400
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1008
18000
1016
18200
18400 ft
1020
LOW
984
17800
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984
LOW
988
992
996
1000
1004
1008
1012
1016
1020
1020
1024
HIGH
1024
1020
1016 mb
LOW
996
1000
1004
1008
1012
1016
1020
17800
18000
1024
HIGH
18200
18400
60
40
40
20°
0°
20°

FIG. 2—SYNOPTIC CHART, 0000 G.M.T., OCTOBER 24, 1945

In these charts the full lines are sea-level isobars and the

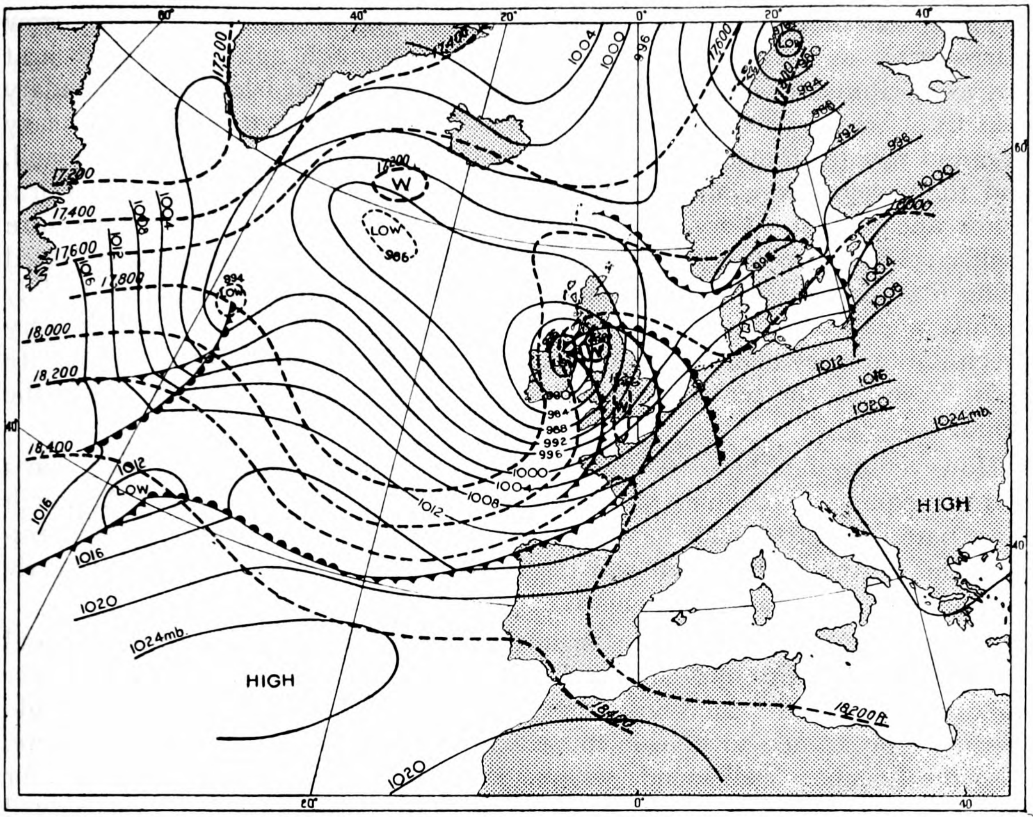
60°
40°
20°
0°
20°
40°
W
LOW
986
994
LOW
LOW
1012
HIGH
1024 mb.
1020
1016
HIGH
1024 mb.
1020
1016
1012
1008
1004
1000
996
992
988
984
980
17,200
17,400
17,600
17,800
18,000
18,200
18,400
18200 ft.
18400
60°
40°

FIG. 3—SYNOPTIC CHART, 0600 G.M.T., OCTOBER 24, 1945

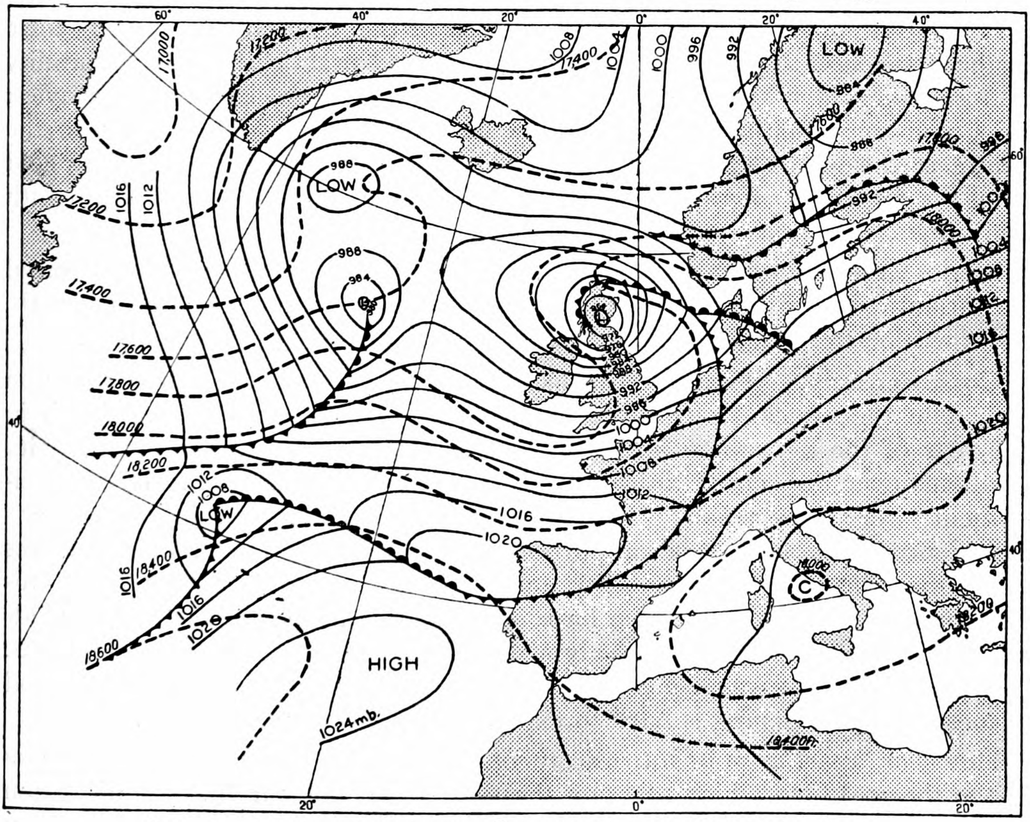
60°
40°
20°
0°
20°
40°
LOW
984
988
LOW
988
984
LOW
1008
1012
HIGH
1024 mb.
1020
1016
1012
1008
1004
1000
996
992
988
C
18000
18400 ft.
18200
17,000
17,200
17,400
17,600
17,800
18,000
18,200
18,400
18600
60°
40°

FIG. 4—SYNOPTIC CHART, 1800 G.M.T., OCTOBER 24, 1945
broken lines are 1000–500-mb. thickness lines.

There was moderate to heavy rain along the occlusion and in the narrow warm sector as it crossed southern England; although lightning was seen at Foynes no thunder was reported anywhere in the British Isles. The secondary cold front which swept round the developing centre, gave continuous heavy rain and squalls in a narrow band along its length as it passed over England, and there were large areas of moderate to heavy rain in the pseudo warm sector ahead of it. Very severe gales developed, especially near the centre itself, and here the heavy rain tended to be general rather than concentrated along the fronts. The more continuous and heavy rain was, however, mainly slightly ahead of the centre from about 0300 onwards, with rather showery precipitation elsewhere. Also after 0900, there was something in the nature of an " eye " at the centre of the cyclone, with no rain and some breaks in the cloud.

However, by far the most impressive aspect of this series of synoptic charts was the sequence of changes in the 1000–500-mb. thickness patterns. Although these patterns were similar to what one would expect over a deepening depression, the degree of distortion and the rapidity of the changes, especially early on the 24th, were most spectacular.

The occasion was marked by saturated or very moist warm-sector air and near-neutral stability in depth, probably to the stratosphere. Very few upper air ascents showed actual instability, although the warming in the pseudo warm sector seemed to be due to vertical ascent in an unstable atmosphere. Also the Leuchars radio-sonde showed the warm air above the front (see for example the 0500 and 1100 G.M.T. ascents on the 24th, Fig. 5) to be saturated and slightly unstable in the upper layers. Both the ascents for 0000 at Valentia and 0800 at Aldergrove (on the 29th), each of them practically at the centre of the depression at the times in question, showed practically neutral stability and relatively dry air (Fig. 6). However, at this stage, by far the heaviest rain, and some of the biggest pressure tendencies were well away from the centre in the warm sector over England. Even after the passage of the cold front the Leuchars ascent continued to show almost saturated air in depth with neutral stability (see 0500 ascent on the 25th, Fig. 5).

Sferics were reported at an early stage near the depression centre as it crossed the Atlantic, but during the period of maximum deepening, early on the 24th, there was no sferic activity except in the open warm sector over France.

Commentary.—It is interesting to discuss these events in the light of equation (2). The 1800 thickness chart on the 23rd (Fig. 1) showed a cold trough in the rear of the depression and a weak warm ridge ahead, but the vorticity gradients over the centre, although of the right sign to suggest cyclonic development, were very small. The subsequent evolution was, in the writer's experience, entirely out of proportion to the primary effect, and it seems likely that the absence of stability damping was an important factor in this development. Moreover, as we have seen, there was evidence that the field-stability effect was acting positively at least at some stage of the development. The appearance of warm pools in the pseudo warm sector during the period of most rapid deepening is hard to explain on any other hypothesis.

However, apart from its intrinsic effect, the stability factor produces changes in the thermal field which react on the thermal-vorticity term. The distortion of the associated thickness pattern due to its own circulation seems to be an essential principle of the organization and self-generation of any depression[1], and the absence of stability (or the presence of instability) would enable the advection to have its full effect, which is not usually the case. The rapid distortion of the pattern in this instance is undoubtedly due to this cause, and, although the thermal-vorticity effect was small initially, it came increasingly into its own as the development proceeded.

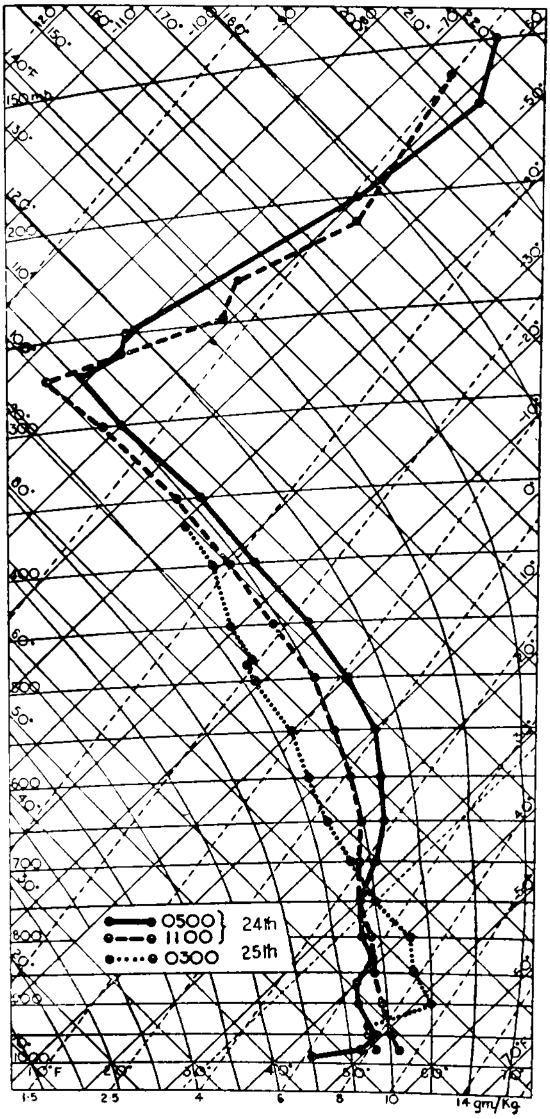

FIG. 5—TEPHIGRAM OF ASCENTS AT LEUCHARS, OCTOBER 24 AND 25, 1945

Erratum.—Ascent on the 25th was also at 0500 G.M.T.

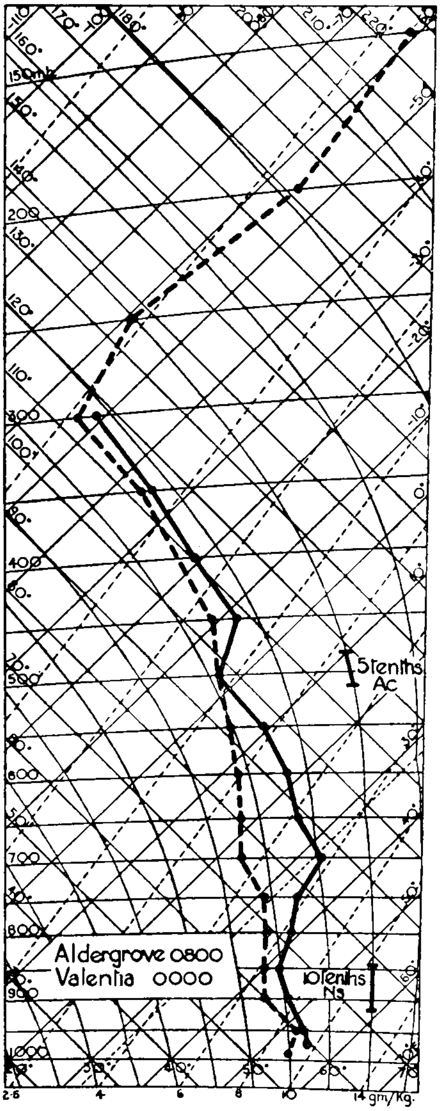

FIG. 6—TEPHIGRAM OF ASCENTS ON OCTOBER 24, 1945

Aldergrove, full line.
Valentia, broken line.

A rough computation of the relative divergence due to the thermal-vorticity term, for the 1000–500-mb. layer and at the centre of the depression at 0000 and 0600 on the 24th, gave values of about 2×10^{-5} sec.$^{-1}$ and 3×10^{-5} sec.$^{-1}$ respectively. These would account for mean vertical velocities of the order of 7–10cm./sec. throughout the layer, which are certainly not excessive. These computations are easily made on thickness maps, but the field-stability term is much more difficult to evaluate since the actual vertical velocities and the degree of instability at the right time and place are unknown. However, a crude assessment may be obtained from the degree of warming in the pseudo warm sector early on the 24th. For the warm pool in the north Irish Sea, at least, the thickness tendency which may be attributed to dynamical heating is about 100 ft./6 hr.; if Γ is expressed as a multiple of the dry-adiabatic lapse rate, $\beta\gamma_a$ say, then it may be shown that the value of the product of $\overline{\beta w'}$ necessary to produce this degree of warming is about 2/3 cm./sec. Thus if S is 1/15 which is the approximate value measured from Leuchars ascent in the upper layers, $\overline{w'} = 10$ cm./sec. which is still quite moderate, and smaller degrees of instability and much larger vertical velocities may well have existed. The general rainfall was mainly confined within a radius of 400 Km. from the centre, and, in order to obtain a conservative estimate, this value was used for R in the expression given earlier. These tentative values give 6×10^{-5} sec.$^{-1}$ for the relative divergence due to the field-stability term. It is evident that actual instability was not present over the entire field, but variations in Γ itself from a maximum negative value (instability) in the region of greatest ascent to zero or positive away from it, would enhance the above value. We may therefore conclude that the field-stability effect during the crucial deepening stage was at least as great as the thermal-vorticity effect, and may have been largely responsible for " triggering off " the marked development.

The tendency for the centre to move erratically during the rapid deepening over Ireland is presumably to be expected in all depressions where instability is present, partly owing to the inhomogeneity of the air masses involved and the rapid distortion of the thermal field which may at times throw the maximum development away from the existing centre. The heavy rain saturated the polar maritime air mass in the vicinity of the centre, and the absence of stability damping may have been important in preserving the intensity of the vortex for several days after. In other cases it has been suspected that genuine re-development in the cold air of a fully occluded depression may have originated in this way, the residual vertical motion in the nearly saturated air having produced a certain amount of latent instability.

Conclusion.—The foregoing analysis does not presume to describe the dynamics of the formation of pressure systems in detail, but it is considered that there is a real sense in which their overall development conforms to the general model adopted. This article is mainly concerned with the importance of atmospheric stability in synoptic developments and shows, in a particular case, something of its inherent effect and its possible relation to the other factors involved.

The field-stability effect depends for its operation on the differential heating and cooling associated with organized fields of vertical motion and is automatically called into play whenever they occur. The formulation takes into account the actual field distribution of the stability and the vertical-motion parameters as they happen to be at a particular instant of time; it represents a real physical process and does not depend on the characteristics of a particular model. It almost invariably acts as a damping factor in nature, but on the rare occasions when near neutral stability or actual instability exists or is likely to be realized by a small amount of lifting, particularly rapid and intense developments are to be expected.

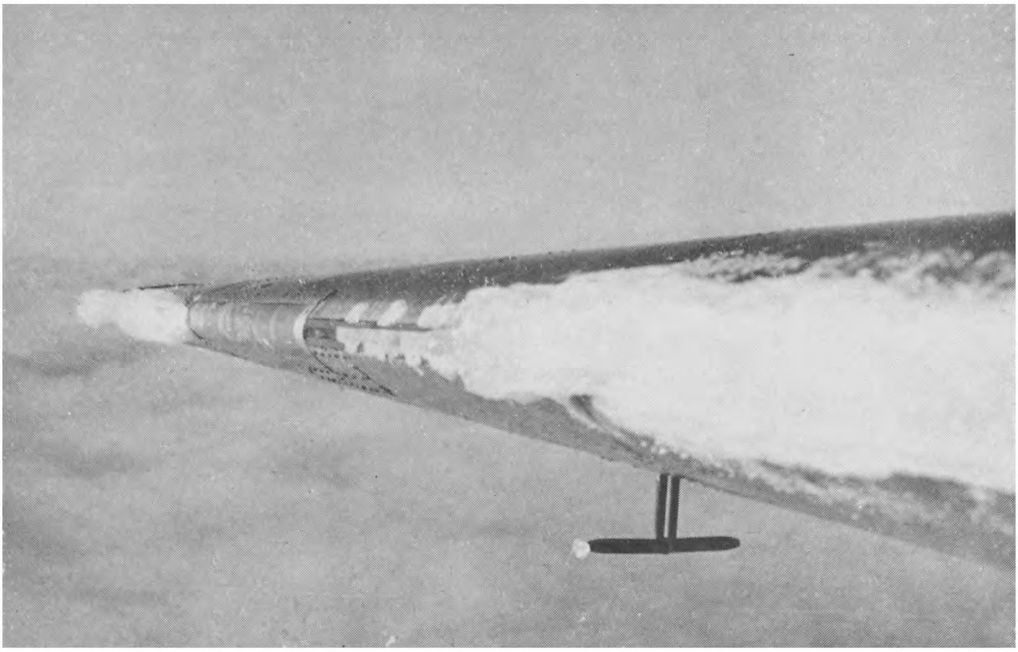

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FIG. 1—ICE ACCRETION ON TAILPLANE, FEBRUARY 27, 1950
The initial ice accretion appeared to be pure rime but later developed into glaze ice
(see p. 140)

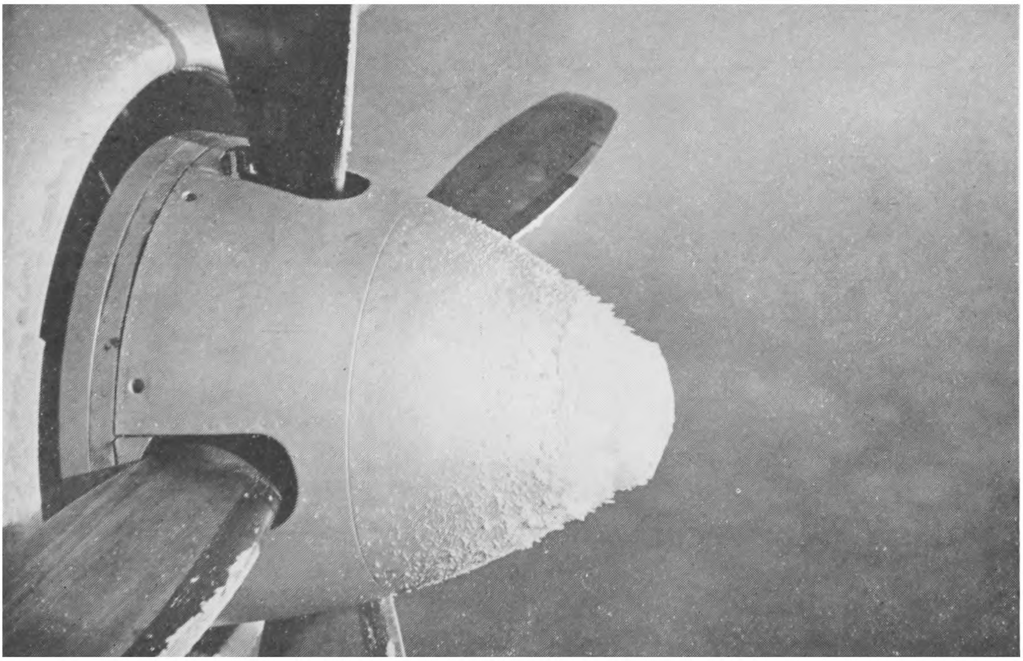

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FIG. 2—ICE ACCRETION ON THE BOSS AND FEATHERED PROPELLOR BLADES OF AN ENGINE AT REST

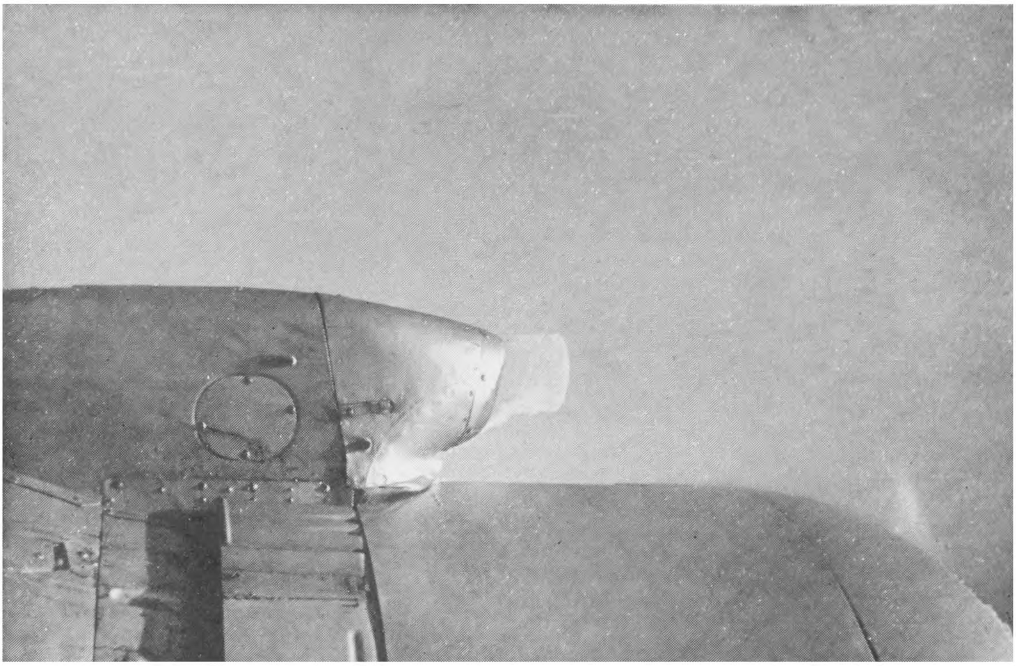

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FIG. 3—ICE ACCRETION ON THE ENGINE INTAKE

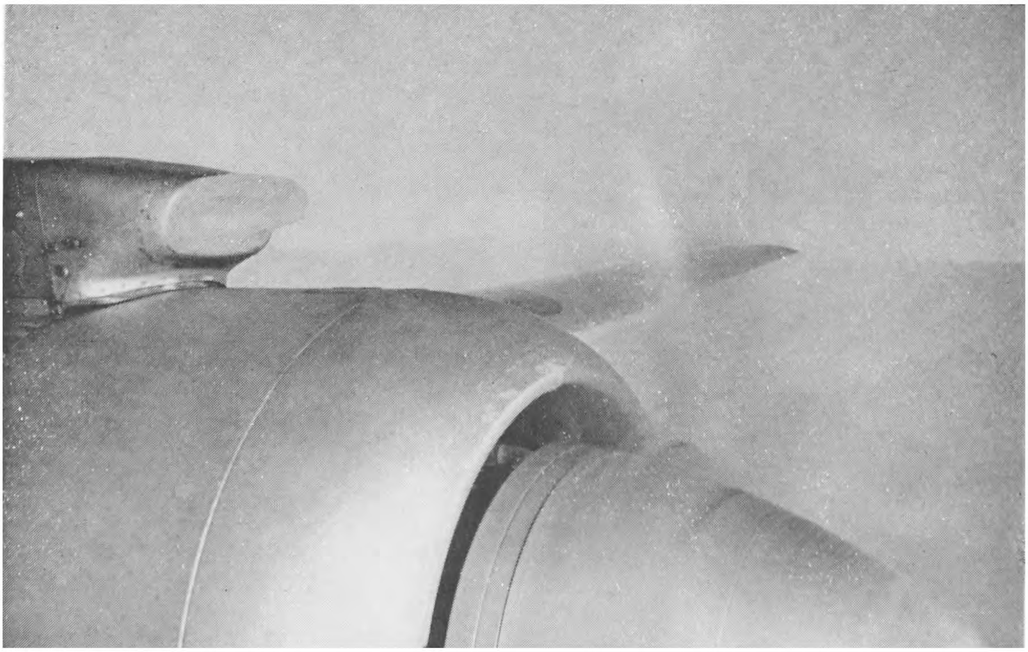

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FIG. 4—ICE ACCRETION ON THE ENGINE INTAKE

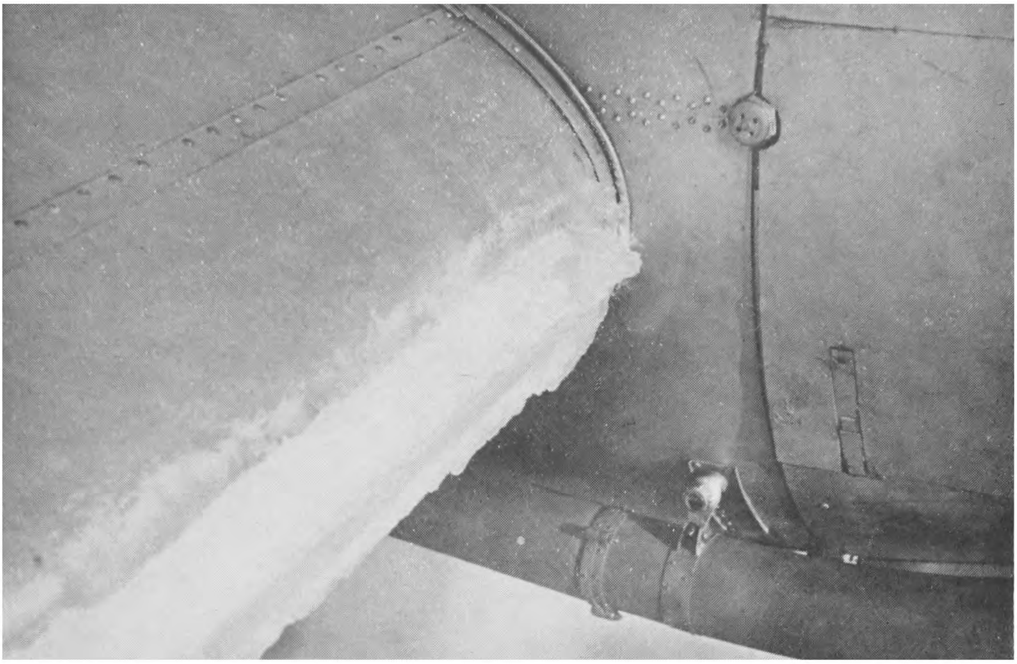

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FIG. 5—GLAZE ICING AT THE MAIN PLANE ROOT

The icing was extremely rough and flowery growing into knife-like projections several inches either side of the stagnation point

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FIG. 1—SIMULTANEOUS OCCURRENCE OF LUMINOUS NIGHT CLOUDS, NEAR HORIZON, AND AN AURORAL ARC WITH SUNLIT RAYS

Photograph taken at Abernethy, Perthshire (56°20′01″N., 3°18′38″W.) at 0008 G.M.T., July 25, 1950.

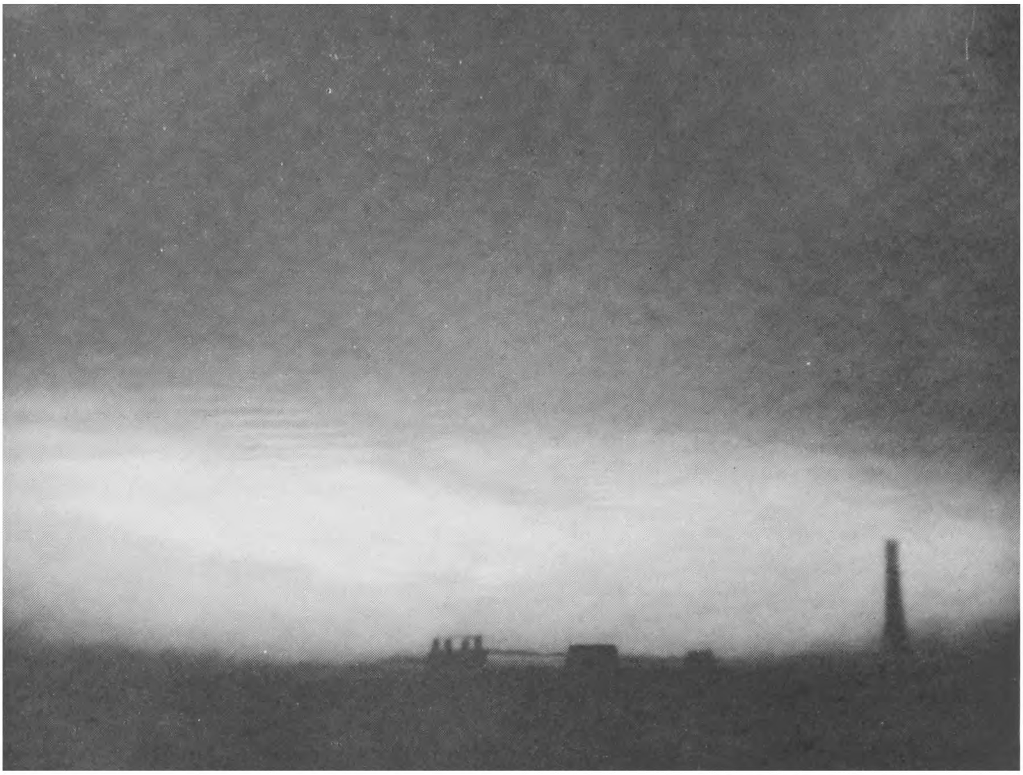

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FIG. 2—LUMINOUS NIGHT CLOUDS SHOWING CHARACTERISTIC WAVE STRUCTURE
Photograph taken at Abernethy, Perthshire, 0148 G.M.T., July 25, 1950

Reproduced by courtesy of J. Paton

FIG. 3—LATER DEVELOPMENT OF LUMINOUS NIGHT CLOUDS, WHICH HAVE NOW EXTINGUISHED THE AURORA
Photograph taken at Abernethy, Perthshire, 0206 G.M.T., July 25, 1950.
Note the characteristic wave structure of the clouds which now extend to an elevation of 24° above the horizon.

The magnitude of the effect is largely dependent on the size of the pressure system, and for large-scale features such as the primary cells of the general circulation or long atmospheric waves it is probably of little direct importance.

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INTERNATIONAL METEOROLOGICAL ORGANIZATION

Northern-hemisphere Polar-Year charts

From August 1932 to August 1933 an International Polar Year was organized during which a concerted effort was made to obtain meteorological and other scientific observations for as large a portion as possible of the northern hemisphere, paying particular attention to the Arctic regions. It will be recalled that Dr. Stagg was in charge of the meteorological station established at Fort Rae in northern Canada.

Arrangements were made by which the Deutsche Seewarte at Hamburg undertook to draw the northern-hemisphere meteorological charts for each day of the Polar Year, and to have them printed for distribution to national meteorological services who financed their printing. At the outbreak of war in 1939, portfolios containing charts covering the period August 1932 to April 1933 had been completed and distributed. When peace returned in 1945, arrangements were made to transfer the remaining material to London. This material included charts for May–June 1933 and tracings for July and August 1–16, 1933.

The May–June charts and the July–August charts have recently been distributed to the subscribers to this project. The Meteorological Office has a number of sets of the charts, which have been distributed as follows: two sets to the Meteorological Office Library, and one set each to the special investigations Branch, the Long-Range Forecasting Research Branch, the meteorological office, Edinburgh, Kew Observatory, and the meteorological offices at Malta and H.Q., Middle East Air Force.

The base maps cover the whole of the northern hemisphere on an equidistant azimuthal projection on the plane through the parallel of 60°N. where the scale is 1:30,000,000. The length of the meridian from pole to equator is about 13 in.

One chart is provided for each day, but the observations plotted on it are not all synchronous. The ships' observations are for 1200 G.M.T. ±1 hour. Over the greater part of Europe, North America and North Africa the time of observation is 1300 G.M.T. Over India and Burma the time is 1130 G.M.T., and over the U.S.S.R. it is 1300 L.M.T. except for eastern Siberia where it is 1900 L.M.T. In some small areas the departures are greater. The charts are kept in special folders holding a month's set each, and a chart of station names and times of observation is included in each set.

The complete plotting scheme with key to all symbols is printed on every chart. The data given for each station include pressure, temperature, relative humidity, pressure change, present and past weather, cloud types and total cloud amount, with the addition for ships of air-sea temperature difference, course and distance traversed in the past three hours. The plotting scheme is that adopted by the International Meteorological Organization Conference of 1935, but it differs little from the one now used and will for the most part be understood without reference to the explanation.

The data for the charts were specially sent by the various national services to the Deutsche Seewarte, and so were much more comprehensive than those received by radio on the day of observation and plotted on current charts. The sea areas, including the Indian Ocean and the tropical Atlantic Ocean, are well covered with ships' observations. There are ten stations north of 75°N. The blank areas are Tibet and Mongolia, central Arabia, a large part of the Sahara, and the Pacific Ocean south-west of California.

Isobars are drawn for every 10 mb. but no other analysis has been placed on the charts. It is noticeable, however, that the isobars are drawn with " frontal " bends.

The charts are more legible and attractive to study than many published charts for very wide areas. The stations have been happily chosen to combine good representation of the weather with legibility and absence of risk of confusion between adjacent stations. The symbols are neatly plotted and are easily read without the aid of a magnifying lens.

The charts should be borrowed from the Meteorological Office Library in sets of months. Also available for lending from the Library are the detailed reports of the observations made at the Polar-Year stations of the various nations. Further, special upper air soundings by aircraft, *ballon-sonde* and pilot-balloon were made by most countries during the Polar Year so that the amount of upper air data available for study in conjunction with the northern-hemisphere charts is greater than for other periods before the introduction of radio-sondes into widespread use.

NOTES ON DE-ICING TRIALS

By R. BOJDYS

In view of the interest aroused by the Meteorological Office Discussion[1] held on October 9, 1950, covering American research into aircraft-icing problems, the following brief note has been prepared regarding some recent British work on the same subject.

During January and February 1950 a series of flight de-icing trials were carried out by the Project Development Branch of British European Airways, using a specially equipped Viking. The flight trials were conducted over a number of areas, including Scandinavia, Germany, the North Sea and the Massif Central in south France.

During the course of the work, some excellent photographs of ice accretion on the aircraft were obtained, these being of special interest in view of the almost complete lack of such pictures taken whilst actually in flight. Some of these are reproduced between pp. 138 and 139. The irregularity of the distribution of the ice shown by the photographs is due to the fact that de-icing fluid was supplied only to certain test sections as part of the investigation. The following details of the five illustrations are given by way of explanation.

Test results, February 27 and 28, 1950.—The flights took place over the North Sea, Trondhjem and Arctic Circle areas at heights of 4,700–8,000 ft. during the period 0930–1230, whilst a ridge of high pressure over Finland was moving slowly westwards. Slight sleet and snow were reported at some coastal stations of northern Norway. The cloud structure consisted of a layer of strato-cumulus, base 1,500–2,500 ft. and tops 4,500–6,500 ft., with variable nimbostratus and altostratus clouds between 7,000 and 9,000 ft. No cumulus clouds were observed during these flights. The ice had the appearance of being of the hard-glaze type. A remarkable accretion of ice on the engine intake will be noted from Figs. 4 and 5. This piece of ice finally broke away when the aircraft descended into warmer air, damaging the de-icing distributor on the starboard side. The reduction in airspeed due to the heavy ice accretion was calculated to have been 47 kt. The recorded aircraft temperatures were between $-8°$ and $-11·5°$C.

I am indebted to the Project Development Department of British European Airways and to Capt. D. Mason, B.E.A., for permission to submit this note. Full details of this work can be found in a report by the Project Development Department of British European Airways.

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2. London, British European Airways, Project Development Department. Vickers Viking fluid de-icing trials 1950. London, 1950.

METEOROLOGICAL RESEARCH COMMITTEE

The 10th meeting of the Instruments Sub-Committee was held on January 25, 1951. The Chairman (Prof. Sheppard) presented a verbal report of encouraging progress which is being made at the Radar Research and Development Establishment on the work of developing a searchlight suitable for investigating the density of the upper air (by measuring the intensity of back scattered light). The Sub-Committee also considered the possibility of using a radar technique for measuring the vertical velocity in cumulonimbus cloud. Recommendations for research on instrumental problems during the next twelve months were agreed.

The Physical Sub-Committee held its 14th meeting on February 8. Some time was spent in considering possible ways of tackling the problem of forecasting the formation and development of radiation fog. The technical papers considered included one by Mr. R. F. Jones[1] on the relation between the radar echoes from convective cloud and the degree of turbulence in the cloud. Recommendations for research on physical problems in meteorology during the next twelve months were agreed.

The main Meteorological Research Committee met for the 61st time on March 15. After hearing annual reports from the Chairmen of Sub-Committees, the Constitution of Sub-Committees and the Research Programme for the next twelve months were approved.

[1] *Met. Res. Pap., London,* No. 593, 1951.

ROYAL METEOROLOGICAL SOCIETY

Recent work on the stratosphere

At the meeting of the Society on February 21, with Dr. R. C. Sutcliffe, a Vice-President, in the Chair, a discussion was held on recent work on the stratosphere.

Sir Charles Normand opened the discussion with some notes on the observation of ozone. It was known that the centre of gravity of ozone was at about 22 Km. (72,000 ft.) and most of the day-to-day variation occurred between 5 Km. (16,500 ft.) and 25 Km. (82,000 ft.). He thought it might be possible to use the quantity of ozone (as measured at the ground by a spectrometer) as a tracer element in the study of the motion of the lower layers of the stratosphere. He showed some up-to-date diagrams of the variation of ozone content compared with the pressure at the tropopause, the temperature at 150 mb. and the reverse of the thickness height, 500–300 mb. They all showed good agreement; but there was occasional disagreement, including an obvious reversal on January 8, 1951, when an occlusion crossed England. He also showed a map of the proposed distribution of ozone spectrometers in western Europe, including four or five in the British Isles (three already in use at Oxford, Downham Market and Camborne) and others in places as far apart as the Azores and Spitsbergen.

Dr. R. Frith, who spoke next, described some humidity measurements made by the Meteorological Research Flight at levels up to 40,000 ft., and, therefore, sometimes not quite in the stratosphere and never very far in. He illustrated an example of a sharp fall of frost point some 2,000 ft. below the tropopause; although the sharp fall usually occurred at the tropopause this sharp fall at a lower level was quite likely in anticyclonic situations. Except for this peculiarity the lapse rate of frost point was approximately the same as that of temperature below the tropopause but considerably greater above, becoming steady at −110°F.

Mr. J. S. Sawyer, the next speaker, considered the synoptic meteorology of the tropopause by inspection of pressure surfaces. In an investigation in the Meteorological Office estimates had been made of the horizontal motion at tropopause level. Potential temperature was conserved at the tropopause and vertical displacements of 1,000 ft./6 hr. had been observed. Thus temperature in the stratosphere was greatly controlled by vertical motion, and air could be observed passing right through a " warm " region. Near jet streams there were sudden discontinuities in the tropopause (a vertical wind shear of 10 kt./1,000 ft. would mean a horizontal change of temperature of about 10°F./100 miles). Mr. Sawyer showed a topographical map of the tropopause with such a tropopause discontinuity round a small area which he called a tropopause " funnel."

Dr. F. J. Scrase then gave an account of further observations made by high-altitude radio-sonde ascents.* The new observations were made at Downham Market and Lerwick, and, to avoid errors due to solar radiation, at 2200 G.M.T. Mean curves showed in winter an increase of temperature with latitude at low stratospheric levels but a decrease at 100,000 ft.; in summer the mean temperature was almost isothermal at low levels in the stratosphere, but increasing again

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*The first observations were reported in this magazine: SCRASE, F. J.; Measurement of wind and temperature up to 100,000 ft. by radio-sonde and radar. *Met. Mag., London*, **78**, 1949, p. 284.

at higher levels up to 100,000 ft. In winter winds were westerly at all levels in the stratosphere, but above 60,000 ft. in summer the wind was easterly; the change-over occurred quite sharply at the vernal equinox but more gradually in the autumn; the maximum easterly velocity occurred very near the summer solstice at higher levels. Comparison of temperatures at 100,000 ft. with those made by other methods at varying latitudes from the Panama Canal Zone to Alaska showed a maximum temperature at about 40°N. in both summer and winter. Day-time temperatures showed differences up to 37°F. although it was fairly certain that at least 80 per cent. of this difference was due to radiation errors.

Dr. G. M. B. Dobson summed up by calling attention to the reasons for the increase in knowledge of the stratosphere: the increase in use of radio-sondes, high-altitude aircraft, higher balloon ascents and now rockets; the information obtained from acoustic experiments and ozone measurements; and, finally, because a lot more people were thinking of the stratosphere. He thought the following problems were most important for the near future:—

(i) General circulation of the atmosphere at least up to 30 Km. (100,000 ft.).
(ii) General radiative equilibrium of the stratosphere.
(iii) Physical meaning of the tropopause.
(iv) Ozone observations, particularly the horizontal and vertical distributions.
(v) Humidity, which can be used as a tracer element more satisfactorily than either tropopause temperature or ozone content.

Dr. Dobson said that an instrument for measuring the vertical distribution of ozone from ground observations was available; it gave readings of the ratio of the intensities of radiation on two wave-lengths in the zenith radiation, and these ratios at sunrise and sunset could be plotted against time on very smooth curves (he showed examples). It was possible to use the spectrometer at night with moonlight or even starlight. A general theory relating these observations to the vertical distribution of ozone was still, however, required.

In the general discussion, Mr. E. Gold agreed with Dr. Dobson that there ought to be a better definition of the tropopause to separate out the different kinds from the general average. Dr. Sutcliffe thought the original definition not too bad, there being only five per cent. of rogues. Miss N. Carruthers thought the tropopause " funnel " mentioned by Mr. Sawyer might be part of a frontal surface; Mr. Sawyer was inclined to agree.

Dr. A. W. Brewer drew attention to the measurements of a steady frost point of −110°F. at high levels by the Meteorological Research Flight, and stated that at that temperature the amount of crystallization in the frost-point hygrometer was so small that the instrument was unreliable.

Prof. P. A. Sheppard was interested in the distribution of ozone with latitude, and was told that the observations at Spitsbergen and Tromsø had shown higher distribution in summer at the poles but lower in winter (although records were only available to mid January as yet); there seemed to be a maximum ozone content at 60°N. in winter.

Atmospheric disturbances in the general atmospheric circulation

At the meeting of the Society held on March 21, 1951, with Dr. R. C. Sutcliffe, a Vice-President, in the Chair, Professor E. Palmén of the University of

Helsinki delivered the Symons Memorial Lecture on the role of atmospheric disturbances in the general atmospheric circulation.

Professor Palmén devoted his lecture very largely to the transfer of angular momentum in the general circulation and in temperate-zone depressions.

He pointed out that the formula for the rate of transfer northwards of angular momentum across a parallel of latitude, integrated over the whole depth of the atmosphere, contained one term proportional to the product of the zonal and meridional velocities (transfer of " u-momentum ") independent of the earth's angular velocity, and a second term proportional to the earth's angular velocity and to the mean of the meridional velocity over the whole depth of the atmosphere (transport of " ω-momentum ").

Over a long period of time the second term vanishes as there is no net meridional transfer of air. Now the area in which angular momentum is transferred from the earth to the atmosphere is the equatorial zone, and the area in which the angular momentum is transferred back to the earth is in the zone of the temperate westerlies. Over a long time, therefore, the maximum rate of northward transfer of angular momentum should be found in the area occupied by the subtropical anticyclones where, however, the surface winds are very light. Professor Palmén showed meridional sections for both the northern and southern hemispheres from which it was clear that there was a maximum of the upper westerlies at about the tropopause level over the surface subtropical anticyclones. Angular momentum thus had to be transferred up to the tropopause level and then carried away northwards. Professor Palmén went on to point out that, though the picture seemed qualitatively clear, considerable difficulty was found when quantitative calculation of the meridional flow was attempted. The angular momentum generated in the equatorial zone was ω-momentum associated with the earth's angular velocity and this had to be converted into u-momentum. This transformation of ω-momentum to u-momentum goes on principally, he considers, at about the 200-mb. level. A vertical circulation was essential to produce a wind distribution such that large-scale eddies can transport the angular momentum polewards.

In the second part of his lecture Professor Palmén considered angular-momentum transport as a factor in temperate-zone depressions. He gave a figure showing that angular momentum was transported northwards in the west and east parts of a depression and southwards in the centre. This transport and associated transformation of momentum into geostrophic wind tended to tilt troughs of low pressure into a south-west to north-east direction.

Professor Palmén next considered the application of angular-momentum theory to the subsidence of the cold air of depressions. The rate of transport of momentum at a specified pressure level is proportional to the difference between the rate of change of the area occupied by the cold air and the rate of change which would be expected at the same level as a consequence of advection alone. This difference in turn depends on the vertical velocity. He gave an interesting table of the subsidence calculated in this way for levels from 900 mb. to 400 mb. behind a cold front.

Finally, he gave a diagram showing his tentative conception of momentum transport along a meridian which shows the main circuit as upward in the equatorial zone, northward from lat. 25° and downwards in the cold air of the depressions of the temperate zone.

LETTER TO THE EDITOR

Simultaneous occurrence of aurora and luminous night clouds

A display of luminous night (noctilucent) clouds, even more extensive and striking than that of July 10–11, 1949[1] was visible above the northern horizon in central Scotland during the night of July 24–25, 1950. Photographs of the clouds taken at Abernethy, Perthshire, are reproduced between pp. 138 and 139.

About 2200 G.M.T., there appeared simultaneously a diffuse auroral arc (with base at an elevation of 10° and sunlit rays) and beneath it luminous night clouds reaching an elevation of 5° (Fig. 1). The appearance together of these two phenomena is surely an extremely rare occurrence.

As twilight waned, the auroral luminescence either ceased or was extinguished by the steadily increasing brilliance of the clouds, which by 0050 G.M.T. had extended to an altitude of nearly 25° and stretched along the horizon between azimuths of 345° and 85° (Fig. 2). Their luminosity was sufficiently great to allow notes to be written without the aid of artificial light.

By contrast with the display of July 10–11, 1949, when the cloud mass remained blue in colour throughout, portions of the cloud in this display were observed to change colour from vivid blue to white, a transformation that suggests growth of the particles.[2] Spectrographic analysis of the light from the clouds during the development of a brilliant display of this kind would be likely to yield valuable information concerning the nature of the cloud particles.

As Professor Størmer had recommended that examination of the clouds by radar should be attempted, search was made during the night from Lerwick Observatory, but no response was obtained. Though the clouds depicted in Fig. 2 were situated over Shetland, overcast skies prevented visual observations at Lerwick.

J. PATON

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REVIEW

Methods in climatology. By V. Conrad and L. W. Pollak. 9½ in. × 6¼ in., pp. xxiv+459, *Illus.*, Harvard University Press (London: Geoffrey Cumberlege) 2nd edn., 1950. Price : $7.50 or 48*s.* 0*d.*

In " Handbuch der Klimatologie " edited by Köppen and Geiger, Dr. Conrad contributed the general section on climatic elements.* The methodological parts of this probably formed the nucleus of the first edition of the book now under review. The latter is a handbook designed for the geographer or climatologist. It encourages in him a critical survey of numerical data and reminds him of the items to be included in descriptions of climate as well as providing him with simple tools for new lines of investigation.

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*KÖPPEN, W. and GEIGER, R.; Handbuch der Klimatologie. Band I. Teil B: Der klimatologischen Elemente und ihre Abhangigkeit von terrestrischen Einflüssen. By V. Conrad, Berlin, 1936.

In the second edition, Dr. Conrad has collaborated with Dr. Pollak, known best perhaps for his papers on periodogram analysis; revisions and additions have been made to the original text, now comprising Part I, and a new Part II has been added, dealing with computing machines and periodicity.

Part I retains, in the main, its simplicity and explicitness, its stressing of small points all too often overlooked; mathematical details are simple, seldom requiring more knowledge than the recognition of a summation symbol; but, in the first five chapters, the reader is greatly harassed by numerous forward references to later chapters. After introductory remarks on climatic elements and the organization of a network of observing stations, there follow chapters on elementary statistics, curve fitting and harmonic analysis. A new chapter, " Aids to computation ", is obscure in parts; but it gives a clear account of simple nomograms and includes a useful list of published tables. In Chapters 6 and 7, climatic elements receive individual study; Chapter 8 deals with comparisons between two or more series of observations and includes correlation; Chapter 9 is concerned mainly with mapping; while Chapter 10 gives notes and hints on the preparation of climatic monographs. Of interest in Chapter 7 is the fitting of frequencies of daily rainfall amounts by a modified form of the Poisson series. The more familiar, binomial and (simple) Poisson series, however, are nowhere mentioned; and neither sequences nor " persistence " of discrete phenomena are discussed.

In Part II, a welcome addition to the volume is the chapter on punched cards and other computing devices; it is easy to read and full of interesting facts. The addition of the three chapters on periodicity however, overburdened as they are with mathematical formulæ, would seem to have increased the cost more than the usefulness of the volume. Brief abstracts of these chapters, supplemented by references, would be more in keeping with the elementary treatment characteristic of Part I, although Fig. 107, illustrating the resolving power of the Schuster spectrum, and the calculation of correlograms from harmonic components are worth including. Discussion of the reality of periodicities in Chapter 13 might well be replaced by a simple, clearly described table of significant amplitudes. The same comment applies to the discussion of the reality of correlation coefficients in Chapter 8*. The authors are not pledged to write a text-book of statistics and so need include only those applications of statistical theory which are necessary for a general, but fairly simple, guide to methods in climatology.

The book is neatly bound, and its smooth pages, clear print and diagrams and ample references to literature make it at once pleasing and useful. It would, however, have been greatly enhanced by more careful revision and editing. Numerous footnotes, duplication of symbols, and references by section numbers, sometimes misprinted, are tiresome things which make for disjointed reading; and, surely, so elegant a publication was worthy of a new line block to eliminate the errors of Fig. 71! There is much to praise, much to criticize; but, happily, the faults are minor ones. The reviewer finds no gravely misleading statements in this second edition, and recommends it, without hesitation, both for lively interest and for reference.

N. CARRUTHERS

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*Compare Table VI of FISHER R. A. and YATES, F.; Statistical tables for biological, agricultural and medical research. 2nd edn, London and Edinburgh, 1943.

OBITUARIES

Prof. Dr. Reinhard Süring.—We regret to report the death on December 29, 1950, of Prof. Süring. He was aged 85.

Prof. Süring was well known to British meteorologists as a pioneer in the investigation of the upper air, as part-author of the later editions of the " Lehrbuch der Meteorologie ", and as part-editor of the *Meteorologische Zeitschrift* and of the " International cloud atlas".

He joined the staff of the Prussian Meteorological Institute in 1890. After working in the Thunderstorm and Instruments Sections at the Central Institute he was appointed Head of the Meteorological Section of the Potsdam Observatory in 1909, and succeeded the magnetician A. Schmidt as Director of the Observatory in 1928. He retired in 1932 on reaching the age limit. He returned to the Observatory in 1945 as Leader of the Meteorological Service of the Soviet Occupation Zone until retiring again in April 1950.

About the turn of the century Süring played a prominent part in the investigations of the upper air by means of manned free-balloon flights conducted by the Deutscher Verein zur Forderung der Luftschiffahrt. He took part in many of the ascents, establishing with Berson a height record for a manned balloon of 10,800m., and worked with Assmann, Berson and others in the study of the observations. The chapters on water vapour and on cloud forms in the monumental publication describing the results of these flights, " Wissenschaftliche Luftfahrten ", were written by him.

In 1908 Süring became part-editor of the *Meteorologische Zeitschrift,* serving successively with Hann, Exner and Steinhauser until that famous periodical ceased publication in 1944. In 1946 he organized the publication of the *Zeitschrift für Meteorologie* of which he was editor until the year of his death.

Hann made him, in 1915, his collaborator in writing the third edition of his " Lehrbuch der Meteorologie ", thereafter known universally as " Hann-Süring". Publication of the fifth edition of the Lehrbuch began under Süring's editorship in 1939 and after much delay owing to the war is now nearly completed.

Smaller works from Süring's pen are his " Leitfaden der Meteorologie ", effectively the Lehrbuch abbreviated, and " Die Wolken " written to supplement the " International cloud atlas " by describing the physics of clouds.

Mrs. E. V. Newnham, M.Sc.—I learned with great regret of the death of Mrs. E. V. Newnham on Sunday, March 11, after a long and painful illness. May I pay a tribute to her memory and express on behalf of her friends in, or retired from, the Meteorological Office their sympathy with her husband and family in their great loss.

Mrs. Newnham, then Miss Gertrude Cocks, entered the Office as a Professional Assistant in the Forecast Branch at South Kensington towards the end of the first world war. She soon showed her ability and Sir Napier Shaw invited her to prepare a memoir on tropical hurricanes about which there was then no comprehensive published account. She undertook the task, no light one as is evident from the following extract from Sir Napier Shaw's preface: " Considering the enormous amount and complexity of the material which is available in various forms and the mixture of theory and fact which can hardly be disentangled in the original papers, the presentation of the salient features of the history of the tropical revolving storms of the globe is not by any means an easy matter."

Meantime she married, but, fortunately, as she was prepared to carry on, a sensible dispensation abrogated in her case the rule about retirement on marriage. She completed the work and produced one of the best memoirs of a memorable series. *Geophysical Memoirs*, No. 19, " Hurricanes and tropical revolving storms " is a standard work of reference and this contribution to meteorological knowledge stands as a permanent memorial of a gifted woman.

E. GOLD

Mr. R. T. Cornish.—It was with great regret that we learned of the death on March 20 of Mr. R. T. Cornish who served as a forecaster in the Meteorological Office from 1941 to 1946.

After he had been with us for eighteen months Mr. Cornish was chosen for a difficult task demanding a high degree of discretion and discernment; by his tact and diplomacy Mr. Cornish fully justified his selection for the post.

Though Mr. Cornish returned to an academic life at the end of the war he did not sever his connexion with the Office. Meteorology was included in the courses he gave as a lecturer in geography at University College, London, and he was a frequent visitor to the Office Library at Harrow where he was always welcome.

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—The part played by o.w.s. *Weather Explorer*, on duty at station JIG, in the search for the missing Globemaster aircraft, U.S.A.F.C-124, during the period March 24–30, 1951, was recognized by the United States Air Force Authorities by a personal signal of appreciation from Major General Anderson.

The Netherlands o.w.s. *Cumulus* relieved the *Weather Explorer* at station JIG on April 7.

Overseas students at the Meteorological Office Training School.—During the past few years a number of overseas meteorological services have asked for forecasting courses to be provided for selected members of their staff at the Meteorological Office Training School. These requests have been complied with whenever possible, the normal practice being to reserve the required number of vacancies on courses which have already been planned for Office staff.

Since the end of the war there have been few forecasting courses which have not included at least one student from abroad. Within the Commonwealth, Ceylon, Nigeria, and Hongkong have sent locally recruited staff to England for training, and students have also come from Europe (Belgium and Greece), the Middle East (Iraq and Persia), Asia (Siam) and South America (Peru).

Language difficulties have not been serious, a fact which bears witness to the widespread knowledge and use of the English language rather than to the linguistic abilities of the instructors.

After their forecasting course at the school the visitors usually spend a few weeks visiting Dunstable and such offices as those at London Airport and Northolt where operational procedures are studied at first hand. Some of the students go to Downham Market to learn about the operation of radio-sonde and radar-wind equipment and students from Ceylon have also visited Eskdalemuir Observatory for instruction in terrestrial magnetism.

Loan of instruments for exploring expeditions.—The exploration societies of the various universities and schools, now planning expeditions to be made during the long vacation, have once more asked the Office to lend instruments for their meteorological work.

Applications for the loan of instruments have been received from the Durham University Exploration Society for an expedition to Breida Merku Jökull (Vatna Jökull) Iceland, from Birmingham University for an expedition to west Spitsbergen, and from the British Schools' Exploring Society for an expedition to central Iceland around the Hofs Jökull Glacier. The main interests of the first two expeditions are geology and glaciology, though meteorology is a necessary handmaiden to these subjects.

The Durham University Exploration Society hopes, with the permission of the Icelandic Government, to set up a permanent climatological station in Iceland.

The meteorological officer to the British Schools' Expedition will be Mr. R. H. A. Stewart who served in the Meteorological Section, R.A.F.V.R., from 1944 to 1947 and afterwards as a civilian in the Office until he took up an appointment as an instructor at Pangbourne Nautical College in 1949.

Climatological stations.—The climatological station at Southend-on-Sea has been maintained for many years by the Pier and Foreshore Department of the local council. When, in February 1951, the Council decided to discontinue full operation of the station, Mr. E. J. Cotgrove and Mr. A. Clothier undertook to take the readings on Sundays so that records would be available for inclusion in the *Monthly Weather Report.* We should like to join with the Council in expressing appreciation to these two gentlemen for their public-spirited action.

Overseas tours.— It will be welcome news to the staff to learn that the length of tour in Mauripur and in Asmara has been reduced to 2½ years.

Mr. R. S. Read, who retired from the Office on December 4, 1950, has been appointed Assistant Librarian of the Royal Meteorological Society.

Retirement of Dr. R. E. Watson.—The Office has lost the services of another of its senior officers in the person of R. E. Watson, Ph.D., who retired on March 31, 1951. Dr. Watson joined the Office in March 1918, having been twice wounded in the 1914–18 war and invalided out of the Army. The first fourteen years of his service were spent on the staff of the Observatories at Falmouth, Kew and Eskdalemuir. He was at Kew Observatory for nine years, first under Dr. Charles Chree and then under Dr. F. J. W. Whipple, and was later Superintendent at Eskdalemuir. This period of Observatory work was most fruitful scientifically: he wrote several papers on radiation and atmospheric electricity, and collaborated with Dr. Chree in two papers on atmospheric pollution and terrestrial magnetism.

From 1934 onwards Dr. Watson was concerned with meteorological services for the Royal Air Force. In the early war years he surveyed war-time requirements of the meteorological training of aircrew. Later he was Senior Meteorological Officer at a group headquarters in Bomber Command with control of a number of subsidiary meteorological offices and took an active part in forecasting for bomber operations. He occupied other highly responsible meteorological posts in Royal Air Force Commands both during and after the war.

At an informal gathering on April 2 the Principal Deputy Director, Dr. Stagg, conveyed the good wishes of the staff to Dr. Watson and asked him to accept a silver cigarette box for which the staff had subscribed. Dr. Stagg referred to Dr. Watson's long association with, and good work for, the Office and made good humoured reference to his qualities of sportsmanship and *bonhomie.* In his reply, Dr. Watson paid tribute to those high-ranking officers in the Royal Air Force with whom he had worked closely and from whom he had received so much willing co-operation, help and appreciation, and to the loyalty and hard work of the meteorological officers who served with him.

WEATHER OF MARCH 1951

Mean pressure of over 1020 mb. extended from Canada to Greenland, while it was above 1030 mb. over parts of north Canada. It was between 1020 and 1010 mb. over North America and also in the area extending from north-west Africa, the west Mediterranean and Spain westwards into the Atlantic. Mean pressure below 1010 mb. occurred over the British Isles and north Europe and also over Italy.

Mean pressure was about 10 mb. above normal in the north-west Atlantic south of Greenland, and about 5 mb. below normal over the British Isles and north Europe.

In the British Isles the weather was unsettled, with depressions constantly passing over or near the country, particularly across England and Wales. It was cold, with frequent showers of sleet or snow, and rainfall was unusually heavy in England and Wales, but less than the average occurred over much of central and western Scotland.

During the first four days of the month a belt of high pressure extended across the British Isles. Weak fronts, however, caused slight rain on the 1st and 2nd, and, on the 4th, a trough over our north-west coasts was associated with some rain in Scotland and Ireland. Widespread fog occurred on the 1st and 2nd. On the 6th and 7th a depression west of Scotland moved south, while a secondary which developed south-westward of Ireland moved east to the western English Channel, and subsequently swung north, then west and finally south-west. Heavy precipitation occurred in the south-west on the 6th, and more was recorded in western districts on the 7th, while thunder was experienced locally in Ireland. By the 9th pressure was high off the south of Greenland; meanwhile a shallow depression over France moved north and another off south-west Norway moved south-south-west and then west-south-west across the north of Scotland. Cold north-easterly winds prevailed on the 9th, becoming rather variable on the 10th; widespread sleet or snow occurred, being heavy in the north of Scotland on the 10th. Thereafter a depression over south-west France moved north-east causing further precipitation (around the 10th–12th snow lay to a depth of 6–12 in. at Dalwhinnie and Glenlivet and at 0900 on the 13th level snow lay 7 in. deep at Bwlchgwyn in north Wales). On the 13th and 14th a deep depression off north Portugal moved quickly north-east across England to the North Sea and thence east across Denmark. Temperature rose and rain occurred on the 13th and scattered, slight rain on the 14th. In the rear of this depression a ridge of high pressure built up over the British Isles giving a rather warm, sunny day on the 15th. From the 16th to the 18th a depression was situated westward of Ireland, while associated secondary depressions moved north-east across England. Temperature continued fairly high in southern districts, while rain fell in most areas and was rather heavy at times in England and Wales. On the 19th the main depression, now situated over south-west Ireland, moved east-south-east, and on the 19th and 20th an anticyclone to the north-west of Scotland moved south-east across the British Isles to the Low Countries; scattered showers, wintry in places, occurred on the 19th and a fair, sunny day (except in the extreme south-west and west) on the 20th. A return to more unsettled conditions ensued on the 21st, when an Atlantic depression moved quickly north-east to the north of Scotland and an associated trough crossed the British Isles; heavy rain was widespread on the 21st, and occurred in the west and north also on the 22nd (2·47 in. at Barnacarry, on Loch Fyne, Argyll, on the 21st, 4·25 in. at Loch Sloy Dam, Dumbartonshire and 3·01 in. at Glen Etive, Argyll on the 22nd). Temperature rose to between 55°F. and 60°F. at a number of stations on the 22nd and in most areas this was the warmest day of the month. The depression moved away east, and by the 23rd was situated over south Sweden, and, in its rear, a cold north-westerly air stream covered the British Isles causing a considerable fall in temperature. From the 24th to the 26th a depression south of Iceland moved east-south-east over the British Isles, later turning east across the North Sea; rather cold weather prevailed, with wintry showers and long bright periods on the 25th and 27th, but more general rain or snow on the 26th. Again, from the 28th to the 30th, another disturbance moved south-south-east from the south of Iceland; rain and snow occurred and the weather continued cold but with long, sunny periods. On the closing day of the month a trough of low pressure moved east across the country causing precipitation, mostly in the form of rain, but sleet or snow in places and local thunderstorms in England and Wales.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	60	19	−2·0	175	+4	83
Scotland	57	3	−2·7	95	+1	82
Northern Ireland ...	57	17	−2·0	97	0	87

RAINFALL OF MARCH 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	3·22	176	*Glam.*	Cardiff, Penylan ...	4·11	130
Kent	Folkestone, Cherry Gdn.	3·31	153	*Pemb.*	Tenby, The Priory ...	4·79	155
,,	Edenbridge, Falconhurst	3·97	160	*Card.*	Aberystwyth	4·23	154
Sussex	Compton, Compton Ho.	5·92	214	*Radnor*	Tyrmynydd	6·92	129
,,	Worthing, Beach Ho. Pk.	3·44	179	*Mont.*	Lake Vyrnwy	6·81	151
Hants.	Ventnor, Roy. Nat. Hos.	4·75	226	*Mer.*	Blaenau Festiniog ...	12·43	144
,,	Bournemouth	3·56	153	*Carn.*	Llandudno	5·27	260
,,	Sherborne St. John ...	4·06	181	*Angl.*	Llanerchymedd ...	4·88	164
Herts.	Royston, Therfield Rec.	3·18	174	*I. Man*	Douglas, Borough Cem.	4·23	143
Bucks.	Slough, Upton... ...	3·56	202	*Wigtown*	Port William, Monreith	3·36	118
Oxford	Oxford, Radcliffe ...	3·55	215	*Dumf.*	Dumfries, Crichton R.I.	2·90	97
N'hants.	Wellingboro', Swanspool	3·28	183	,,	Eskdalemuir Obsy. ...	5·30	108
Essex	Shoeburyness	2·13	158	*Roxb.*	Kelso, Floors	2·87	147
,,	Dovercourt	2·59	168	*Peebles*	Stobo Castle	2·50	86
Suffolk	Lowestoft Sec. School ...	2·59	161	*Berwick*	Marchmont House ...	3·13	118
,,	Bury St. Ed., Westley H.	3·86	204	*E. Loth.*	North Berwick Res. ...	2·58	137
Norfolk	Sandringham Ho. Gdns.	3·95	208	*Midl'n.*	Edinburgh, Blackf'd. H.	2·58	131
Wilts.	Bishops Cannings ...	3·52	156	*Lanark*	Hamilton W. W., T'nhill	2·25	81
Dorset	Creech Grange... ...	5·09	180	*Ayr*	Colmonell, Knockdolian	3·28	97
,,	Beaminster, East St. ...	4·38	149	,,	Glen Afton, Ayr San ...	4·46	106
Devon	Teignmouth, Den Gdns.	4·57	176	*Bute*	Rothesay, Ardencraig...	3·72	104
,,	Cullompton	4·40	161	*Argyll*	Morvern (Drimnin) ...	4·47	92
,,	Ilfracombe	4·84	168	,,	Poltalloch	4·10	107
,,	Okehampton, Uplands	5·75	139	,,	Inveraray Castle ...	5·42	85
Cornwall	Bude, School House ...	4·68	192	,,	Islay, Eallabus... ...	4·07	107
,,	Penzance, Morrab Gdns.	5·39	168	,,	Tiree	3·01	90
,,	St. Austell	5·65	164	*Kinross*	Loch Leven Sluice ...	3·52	118
,,	Scilly, Tresco Abbey ...	4·91	187	*Fife*	Leuchars Airfield ...	2·27	116
Glos.	Cirencester	3·91	169	*Perth*	Loch Dhu	4·88	74
Salop	Church Stretton ...	5·20	216	,,	Crieff, Strathearn Hyd.	1·92	60
,,	Shrewsbury, Monksmore	4·15	249	,,	Pitlochry, Fincastle ...	1·91	69
Worcs.	Malvern, Free Library	4·62	238	*Angus*	Montrose, Sunnyside ...	2·54	122
Warwick	Birmingham, Edgbaston	5·14	269	*Aberd.*	Braemar	2·37	80
Leics.	Thornton Reservoir ...	3·37	183	,,	Dyce, Craibstone ...	2·89	109
Lincs.	Boston, Skirbeck ...	3·19	205	,,	Fyvic Castle	3·07	113
,,	Skegness, Marine Gdns.	3·03	183	*Moray*	Gordon Castle	3·02	130
Notts.	Mansfield, Carr Bank...	4·28	205	*Nairn*	Nairn, Achareidh ...	1·44	78
Derby	Buxton, Terrace Slopes	7·85	190	*Inverness*	Loch Ness, Garthbeg ...	2·13	64
Ches.	Bidston Observatory ...	4·28	225	,,	Glenquoich	5·94	61
Lancs.	Manchester, Whit. Park	4·57	202	,,	Fort William, Teviot ...	3·74	56
,,	Stonyhurst College ...	4·51	122	,,	Skye, Duntuilm ...	3·05	69
,,	Squires Gate	4·44	196	*R. & C.*	Tain, Tarlogie House...	2·05	91
Yorks.	Wakefield, Clarence Pk.	2·92	162	,,	Inverbroom, Glackour...	4·03	81
,,	Hull, Pearson Park ...	2·85	157	,,	Applecross Gardens ...	3·00	64
,,	Felixkirk, Mt. St. John	2·80	142	,,	Achnashellach	4·88	72
,,	York Museum	2·69	160	,,	Stornoway Airfield ...	2·44	63
,,	Scarborough	3·34	186	*Suth.*	Loch More, Achfary ...	6·08	94
,,	Middlesbrough... ...	3·13	199	*Caith.*	Wick Airfield	3·65	161
,,	Baldersdale, Hury Res.	3·59	116	*Shetland*	Lerwick Observatory ...	2·46	78
Norl'd.	Newcastle, Leazes Pk....	3·58	174	*Ferm.*	Crom Castle	3·19	103
,,	Bellingham, High Green	3·08	105	*Armagh*	Armagh Observatory ...	2·78	118
,,	Lilburn Tower Gdns. ...	3·74	141	*Down*	Seaforde	3·03	104
Cumb.	Geltsdale	4·33	155	*Antrim*	Aldergrove Airfield ...	2·09	83
,,	Keswick, High Hill ...	4·46	99	,,	Ballymena, Harryville...	2·20	70
,,	Ravenglass, The Grove	4·35	141	*L'derry*	Garvagh, Moneydig ...	2·67	86
Mon.	Abergavenny, Larchfield	4·55	150	,,	Londonderry, Creggan	3·31	103
Glam.	Ystalyfera, Wern House	6·45	120	*Tyrone*	Omagh, Edenfel ...	3·33	106

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FIRST CONGRESS OF THE WORLD METEOROLOGICAL ORGANIZATION

By E. G. BILHAM, B.Sc., D.I.C.

The First Congress of the World Meteorological Organization (W.M.O.) was held at the Hotel du Palais d'Orsay in Paris from March 19 to April 28, 1951. It was attended by delegates and advisers representing 58 members of the Organization, and by observers representing the International Union of Geodesy and Geophysics, the United Nations Organization and many of the specialized agencies having interests in meteorology. The total number of persons present in one or other of these capacities was about 150.

The International Meteorological Organization, which has now ceased to exist, was formed in 1878 to facilitate the international exchange of meteorological information. It was a semi-official association of the directors of national and territorial meteorological services, who attended its conferences in that capacity and not as representatives of governments. Following upon earlier discussions at which the need for an international body, representative of governments, to replace the International Meteorological Organization was agreed in principle, a Convention was drawn up at the 12th Conference of Directors, held in Washington in 1947, to establish a World Meteorological Organization. The Convention, which has been published by H.M. Stationery Office (Cmd. 7427), establishes the World Meteorological Congress as the supreme body of the Organization and provides that Congress should meet at intervals not exceeding four years. Other organs established by the Convention are the Executive Committee, Regional Associations, Technical Commissions and the Secretariat.

The deed of transfer of the assets, functions and responsibilities of the International Meteorological Organization to the World Meteorological Organization was signed on April 4, 1951. From that date the International Meteorological Organization ceased to exist and the World Meteorological Organization came effectively into being. The task before the First Congress was thus a very onerous one. It had to create, *ab initio*, a new organization and to agree upon the measures necessary to ensure its smooth functioning within the broad framework of the Convention. Much of this work was of administrative, legal or financial character and the larger delegations included experts in these fields.

At the first session Congress elected Sir Nelson Johnson, principal delegate of the United Kingdom and outgoing President of the International Meteorological Organization, as Chairman of the First Congress. Other representatives of the United Kingdom were Mr. H. T. Smith (Air Ministry Secretariat), Mr. E. G. Bilham (Meteorological Office), Capt. R. F. Nichols, R.N. (Director of the Naval Weather Service), Inst. Capt. P. Bracelin (Naval Weather Service), Mr. J. Price (British Embassy), Mr. J. Riley (Ministry of Civil Aviation) and Mr. A. W. Ireland (A.-E. Sudan). Cdr. C. E. N. Frankcom, R.N.R. (retd.), was present for part of the time in his capacity as outgoing President of the International Meteorological Organization Commission for Maritime Meteorology.

The meetings in plenary session were much facilitated by the use of the simultaneous interpretation system. Each participant was provided with a pair of head-phones and a switch so that the English, French, Spanish or Russian version of everything spoken could be heard at will.

It would be impossible to set out all the results achieved at the Congress within the compass of a short article. We shall therefore confine attention to those items of the agenda likely to be of most interest to readers of this Magazine.

Officers of the Organization.—The following were elected to hold office until the end of the Second Congress: President, Dr. Reichelderfer (United States); First Vice-President, M. Viaut (France); Second Vice-President, Mr. Sellick (Rhodesia).

Executive Committee.—The Executive Committee consists of the Officers, the Presidents of the six Regional Associations (see below) and six additional elected members. The following were elected: Johnson (United Kingdom), Zolotukhin (U.S.S.R.), Hesselberg (Norway), Azcarraga (Spain), Ferreira (Portugal), Aslam (Pakistan).

Regional Associations.—Congress established six Regional Associations to continue the work of the six Regional Commissions set up by the International Meteorological Organization in 1946. An important change now introduced is to include the oceans as well as the land areas in the regions. Thus Region VI (Europe) includes not only Europe but also the eastern half of the North Atlantic Ocean. The Regional Associations, membership of which is confined to directors of services having networks extending into the regions concerned, met during the Congress and elected the following presidents and vice-presidents:—

ASSOCIATION	PRESIDENT	VICE-PRESIDENT
Region I (Africa)	Davies (British East Africa)	Fahmy (Egypt)
Region II (Asia)	Sohoni (India)	Zolotukhin (U.S.S.R.)
Region III (South America)	de Souza (Brazil)	Monasterio (Argentine)
Region IV (North and Central America)	Thomson (Canada)	Peña-Aguirre (Mexico)
Region V (South-west Pacific)	Barnett (New Zealand)	del Rosario (Philippines)
Region VI (Europe)	Lugeon (Switzerland)	Lambor (Poland)

Technical Commissions.—Congress had to consider what Technical Commissions should be established (the general aim being to keep the number to a minimum) and to determine their terms of reference. At a later stage, after decisions had been reached on these questions, Congress "went into

Commission " and elected presidents to hold office until the first full meeting of each Commission. Eight Commissions covering the following fields of responsibility were established as listed below, with their presidents:—

COMMISSION	PRESIDENT
Bibliography and Publications	Mézin (France)
Instruments and Methods of Observation	Patterson (Canada)
Aerology	van Mieghem (Belgium)
Climatology	Thornthwaite (United States)
Agricultural Meteorology	Burgos (Argentine)
Maritime Meteorology	Frankcom (United Kingdom)
Synoptic Meteorology	Bleeker (Netherlands)
Aeronautical Meteorology	Nagle (United States)

The Synoptic and Climatological Commissions also elected as Vice-Presidents, Dr. Björkdal (Sweden) and Dr. Basu (India) respectively.

Secretariat.—The Secretariat will be established at Geneva and will include both an Administrative Division and a Technical Division. Congress appointed Dr. G. Swoboda to the post of Secretary-General. In the newly created Technical Division individual officers will be nominated to act as permanent secretaries of each Technical Commission.

Technical regulations.—Immediate steps will be taken to prepare and publish technical regulations covering meteorological practices and procedures. These will be arranged under subject headings and will provide members for the first time with a succinct and complete statement of the technical practices with which they are expected to conform.

Cloud atlas.—Work is well advanced on the preparation of a new " International cloud atlas " and provision has been made in the World Meteorological Organization budget for its publication before the next meeting of Congress.

Technical assistance.—Congress resolved that the World Meteorological Organization should participate in the United Nations Expanded Program of Technical Assistance for Economic Development of Under-Developed Countries.

Networks.—The World Meteorological Organization will take all appropriate measures to ensure adequacy in the world network of meteorological stations. In the event of a serious gap, it will examine ways of bridging it either by means of collective aid, financing out of special funds, or by agreement with one or more countries.

Publications.—The Secretariat will produce a periodical bulletin for the purpose of keeping members informed of international meteorological activities. Consideration will also be given to the publication of condensed statistics of basic meteorological data either in tabular or chart form.

Social.—Our French hosts arranged a number of pleasant social functions, including some specially planned for the entertainment of the wives of delegates. On April 19 delegates attended a reception by the President of the French Republic at the Palais de l'Elysée. A reception given by the American Delegation at the Hotel du Palais d'Orsay made a pleasant conclusion to the Congress.

ZONAL AND OTHER INDICES

By A. G. FORSDYKE, Ph. D.

The "zonal index" has attained some prominence in meteorological literature during recent years, largely owing to the part which it has played with other indices of atmospheric circulation in American extended-forecasting technique. To see it in proper perspective however it is desirable first to give a little consideration to indices in general.

In meteorology an index is a number, usually derived by a process of averaging, which expresses some large-scale property or process in the atmosphere. Indices were first used by a number of early workers in statistical investigations connected with long-range forecasting. Among the indices used by Walker, for example, was the " North-Atlantic oscillation ", a linear combination of mean values of pressure and/or temperature taken over a specified period at selected stations in the North Atlantic. He correlated this quantity with numerous others expressing seasonal weather characteristics for particular and often remote regions. Similar statistical work with indices was described by Exner, Defant, Baur and Brooks in many original papers, references to which will be found in Sir Napier Shaw's " Manual of meteorology ", Vol. II, Chapter VII.

Circulation indices.—The main emphasis with regard to indices in recent years has been on their use as measures of the strength of the atmospheric circulation, and as possible indicators of large-scale weather types. Goldie[1], for example, used the annual mean pressure differences between certain stations in Scotland as indices of the mean south-north and west-east air flow over the British Isles. He found interesting relations between these indices and the broad weather characteristics for this country, years of maximum west-east flow, for example, corresponding to conditions somewhat warmer and drier than average. More recently, Jones[2] used the daily difference of pressure between the Azores high and the Iceland low as a measure of the strength of the westerlies on the north-east Atlantic. There was some suggestion of periodicities ranging from 6 to 72 days in the occurrence of extreme values of this index.

The zonal indices introduced in America were devised to represent the strength of the circulation in a specified band or sector of the northern hemisphere. They are computed systematically for a network of points which usually has a fixed geometrical basis, determined by the mean positions of the main branches of the " normal " planetary circulation. The zonal westerly index of Rossby[3,4] is typical; it is the mean speed of the surface westerlies between 35°N. and 55°N. calculated by taking the mean pressure difference between those latitudes on equally spaced meridians and converting by means of the geostrophic relation. Corresponding indices for other branches of the circulation have been defined, the three principal surface zonal indices being:

Polar easterlies, 55–70°N.
Prevailing westerlies, 35–55°N. (often referred to as *the* zonal index).
Subtropical easterlies, 20–35°N.

There are corresponding indices for the standard upper levels of synoptic meteorology. In America attention has been given chiefly to the 700-mb. level, and mean values of the indices at this level and at the surface have been computed for use in extended forecasting.

The planetary wind belts are sometimes considerably displaced from their normal latitudes, overlapping the next zone, and then the principal indices as defined above, while giving some indication of the abnormal distribution, would fail to show the strength of the circulation. To meet this difficulty the so-called maximum–minimum or modified indices have been devised; they are computed for a variable zone for which the mean flow is a maximum when averaged over the whole or half hemisphere as the case may be.

Some other indices devised to represent particular aspects of the atmospheric circulation may be briefly mentioned. The " meridional index " is a measure of the total flow of air across a selected parallel of latitude at a specified level. If computed on the geostrophic assumption, with variations of density neglected, this index obviously gives equal northward and southward components when taken round the hemisphere—that is zero net flow. The true net flow for the whole depth of the atmosphere may be obtained from the variation of the " total-mass index " expressed by the integral of the surface pressure over the polar segment bounded by the given latitude. The " solenoidal index " is computed in the same way as a zonal index but using the thickness (or mean virtual temperature) for a specified pressure interval. This is, in effect, a " thermal-wind index " and may alternatively be found as the difference between the zonal indices for the two levels. "Transport indices" provide measures of the resultant flux, across a specified latitude, of such physical properties as momentum and heat content of the air. They are computed by integrating the product of the meridional velocity with the zonal velocity (momentum transport) or the temperature and water-vapour content (sensible and latent heat transport) round the selected circle of latitude, as for example in a recent paper by Priestley[5].

Indices and the general circulation of the atmosphere.—*Mechanism of the general circulation.*—Indices providing numerical measures of properties or processes in the atmosphere on a large scale are an obvious and even essential aid to the study of general circulation problems. Some understanding of the working of the circulation may be sought through possible correlations among the various indices. The most extensive work in this field is that described by Willett[6,7,8] in a series of voluminous unpublished reports. The following summary of Willett's results is taken from a detailed and critical review prepared by Mr. E. J. Sumner in the Meteorological Office.

Willett calculated contemporary and lag correlation coefficients for almost every possible combination of index pairs amounting to many thousands in all. The coefficients obtained were almost invariably low, the highest absolute values obtained lying between about 0·30 and 0·40 with a few exceptions. Correlation coefficients of this magnitude are not without significance but they have little practical value. Moreover when the indices were corrected for seasonal trend the correlation coefficients were often reduced to complete insignificance. Results of little or no significance were also obtained when monthly mean indices were correlated for the northern and southern hemispheres. When indices were correlated with certain solar phenomena such as sunspot number and monthly mean pyrheliometric value the coefficients were also quite small on the whole.

As might be expected, Willett's conclusions[7] from these results do not encourage the idea that indices can be profitably used in studies of general-circulation problems. They would appear to indicate that the processes which control the fluctuations of the strength of the circulation are not revealed by these particular indices. It may be that the controls are situated outside the portion of the atmosphere studied, for example in the stratosphere or in very low latitudes where observations are scanty; or they may be situated outside the atmosphere altogether, for example the earth's surface influences or solar phenomena. It is, however, well to recognize, as indeed Willett himself does, that there is a certain unreality about indices calculated on the basis of a geometrical network of points without regard to geographical features. Moreover, owing to the process of averaging by which they are computed these indices cannot specify important details of the prevailing circulation. It is difficult to believe that the fluctuations of the atmospheric circulation are without some degree of internal control; it appears however that these indices are not a suitable means of revealing it.

Among these generally low correlation coefficients obtained by Willett there was, however, one relating to transport indices which appeared to have some significance. Theoretical work by Prof. V. P. Starr (unpublished) having indicated the likelihood of a connexion, Willett investigated the contemporary correlation between the pressure deficit from normal northward of latitude 45°N. and the transport of heat across the same parallel. The resulting correlation coefficient 0·52, was substantially higher than most coefficients hitherto found for circulation indices. This result conforms with the view that transport indices are useful aids towards an understanding of the mechanism of the general circulation. The transport of heat and momentum across a given circle of latitude are obvious factors to consider as affecting the strength of the circumpolar circulation and the intensity of the " cold pole " in high latitudes. Considerable attention is being given to these processes by workers in several countries.

Relation of indices to large-scale circulation types.—It would appear not unreasonable to expect that one of the uses of indices might be as convenient indicators of large-scale weather types in the sense that particular values or ranges of values of an index could be recognizably associated with characteristic types of circulation. It has been found however that the value of indices in this connexion is very limited. For example, a high value of the zonal westerly index is associated with low pressure near latitude 55°N. and high pressure near 35°N. over a large part of the hemisphere, so that the Icelandic and Aleutian lows and the subtropical highs are all well developed. On the other hand a very low or negative value of this index is associated with a type in which the pressure systems are elongated in the north-south direction or with an " inverted " type with high pressure to the north and low pressure to the south of the middle-latitude belt. These associations were pointed out by Namias[9] and Willett[8]. These typical patterns are commonly referred to as " high " and " low " index types. But it was quickly realized that use of an index as a type indicator is limited to the few occasions on which it takes extreme values; any intermediate value may be associated with a number of different circulation types, or indeed with patterns having no semblance of type or order at all.

It is worth remarking that the above index and type associations apply to surface indices only, a fact not realized in the early studies of these indices. Namias[10] concludes that the upper westerlies often reach their greatest strength when the surface zonal index is low. This is confirmed by the small correlation coefficients between the surface and upper indices found by Willett[6]. In this connexion Namias[10] remarks that the terms " high " and " low " index type appear to be misnomers. Certainly, the use of these terms as implying vigorous or weak circumpolar westerlies throughout the troposphere, introduced in earlier works on this subject, now seems improper.

Indices in relation to medium-range forecasting.—The prominence given to indices in recent years has been largely on account of their study in connexion with the extended-forecasting project in the United States (R. A. Allen and collaborators[11]). In the earlier reports on this project it was implied, if not explicitly stated, that certain indices, zonal indices in particular, were sufficiently precise indicators of circulation types for their forecasting to be a worth-while problem in itself. It must, however, be reiterated that it is only when the indices take extreme values that they give any indication of the associated circulation patterns.

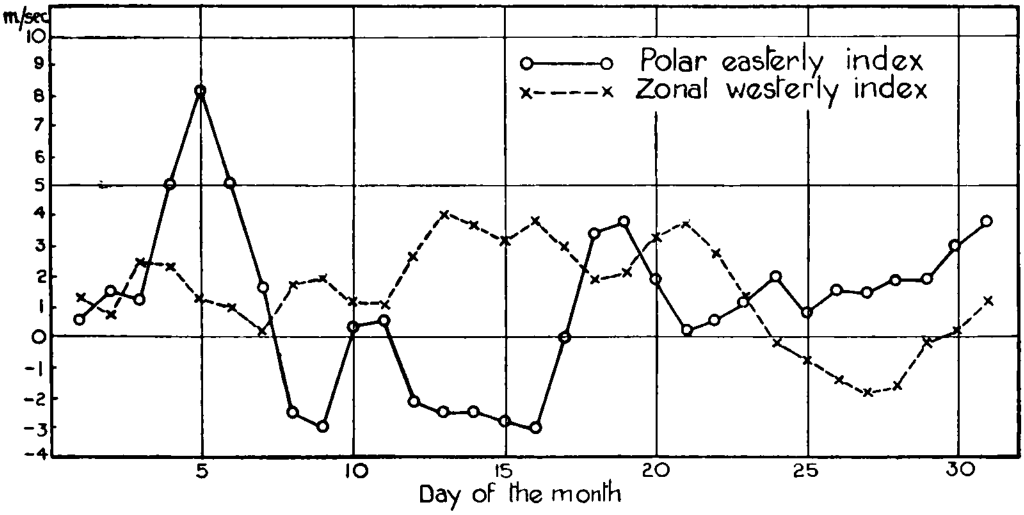

FIG. I—DAILY VALUES OF THE POLAR EASTERLY AND ZONAL WESTERLY INDICES IN THE HALF-HEMISPHERE, ROCKIES TO THE URALS, MARCH 1950

Nevertheless, considerable attention has been given to the problem of forecasting indices. For this purpose it has been the practice in America, and also to some extent in this country in connexion with experimental four-day forecasting, to prepare graphs showing the time variation of certain indices. As examples of these the daily values of the zonal westerly and polar easterlies for the half hemisphere from the Rockies to the Urals for a typical month are shown in Fig. 1. The graphs almost invariably show the irregular and sometimes quite large fluctuations from day to day which are so characteristic of many meteorological time-variation curves. No method of forecasting these changes appears to have been put forward yet, apart from the ordinary statistical rule that if the value of the index departs widely from the normal the most probable change will be back towards the normal. The work of Willett shows that indices have no significant lag correlations or periodicities. It is evident that the forecasting of indices statistically is not a very promising field of inquiry.

It has been claimed that it is occasionally possible to see long-period trends in indices which may be indicative of impending type changes. Evidence on this point, however, is far from convincing both in our own experience and in the literature, and it is doubtful whether the detection of such trends is a really objective process. An index trend might perhaps be useful in giving added weight to a conclusion arrived at by other reasoning.

In the course of the work referred to earlier in this article Willett investigated contemporary and lag correlations between circulation indices calculated for the quadrants of the hemisphere separately. The results showed nothing significant, indicating that little help is to be got from the application of indices to the idea that bands of strong zonal circulation tend to be propagated eastward from sector to sector.

There is however one indirect use of indices in forecasting which should be mentioned. That is their application as a parameter in formulæ for the movement of long atmospheric waves, the atmospheric flow patterns indicated by the large-scale troughs and ridges on upper air contour charts. The best known of such formulæ is that due to Rossby[3]; it is

$$c = U - \frac{\beta L^2}{4\pi^2}$$

where c is the velocity of the wave-pattern, U the general west-to-east velocity of the air stream, β the rate of change northwards of the Coriolis parameter and L the wave-length. This formula, or modifications of it, has been used in the medium-range forecasting problem, sometimes quantitatively but more often to give a very rough approximation to the " stationary wave-length " obtained by putting $c=0$; if the actual wave-length is near this stationary value it seems reasonable to assume that departures from it will take place only slowly, that is, the large-scale situation is relatively static. The significance for our present subject is that the quantity U in the formula is conveniently taken as one of the zonal indices, preferably an index based on a latitude band, selected for each case in accordance with the current location of the zone of main flow.

Conclusions.—We conclude that zonal and similar indices have little application either to problems of practical forecasting or to studies of the general atmospheric circulation. Investigation has revealed neither any recognizable regularity in the variations of these indices such as might be used in forecasting nor any statistical relations which might aid an understanding of the mechanism of the general circulation. For the most part they show no significant periodicities neither do they throw any light on the possible connexion between variations of the atmospheric circulation and solar phenomena. This however does not necessarily mean that such periodicities or connexions have no existence, but simply that the indices considered do not appear to be suitable for revealing them.

Acknowledgement.—I wish to express my thanks to Dr. R. C. Sutcliffe for his helpful criticism in the preparation of this article and an earlier paper on which it is based.

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VARIATIONS OF THE WINTER MEANS OF TEMPERATURE, WIND SPEED AND SUNSHINE, AND THEIR EFFECT ON THE HEATING REQUIREMENTS OF A HOUSE

By R. E. LACY, B.Sc.

In the course of experimental work on house heating it was required to determine the likely variation in the fuel requirements of a particular house from winter to winter. From measurements made in the house over two winters an equation had been determined, connecting the daily heat requirement of the house with the mean outside air temperature, mean wind speed and duration of bright sunshine. Now it can be shown that this equation may be used to predict the fuel requirement for the house for the whole of a winter, given the mean values of the elements for that winter. It is not necessary to know the individual daily values of the elements.

The equation used to predict the daily fuel requirement of the house is of the form

$$H = a + b\,\Delta t + c\,v\,\Delta t + d\,S \qquad \dots (1)$$

where:

H=fuel requirement
Δt =difference between mean house and air temperatures
v =mean wind speed
S =duration of bright sunshine
a, b, c, d are constants.

The house under consideration was heated throughout the winter to a uniform temperature of 65°F., and the equation* derived from the observations was

$$H = -\ 13{\cdot}87 + 3{\cdot}02\,\Delta t + 0{\cdot}098\,v\,\Delta t - 1{\cdot}01S \qquad \dots (2)$$

With these values of the constants the heat requirement H is obtained in kilowatt-hours, when temperature is measured in degrees Fahrenheit, wind speed in miles per hour and sunshine duration in hours.

As noted above, this equation can be used to predict the overall fuel requirements over a period by substituting the mean values of the elements for that period and multiplying the result by the number of days in the period.

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* These equations have been derived from heating trials on two temporary bungalows, the work on which is to be submitted for publication elsewhere.

For a heating season of 212 days this particular equation gives an estimate of the total fuel requirement for the house with a standard error of estimate of about 1 per cent. provided the values of temperature, wind speed and sunshine used do not differ greatly from those from which the equation was derived.

However, the variance in the fuel requirement of the house from winter to winter may be determined without calculating the requirements for each winter. It may be derived from the variances of the individual elements by the following relationship:

$$\mathrm{var}\,(H) = b^2\,\mathrm{var}\,(\Delta t) + c^2 v^2 \mathrm{var}\,[(\Delta t)] + c^2\,(\Delta t)^2\,\mathrm{var}\,(v) + d^2\,\mathrm{var}\,(S) \quad . \; . \; . \quad (3)$$

In these equations we are using Δt, the difference between the temperatures of the house and the outside air, but as the house temperature is assumed to be constant, the variance in Δt is the same as the variance in the air temperature.

The house for which equation (2) was derived is situated at Garston, Hertfordshire, but as the required meteorological data for this locality were not available for more than a few winters it was decided, for the purpose of this investigation, to use data obtained at Kew Observatory during the period 1919–49. Monthly means of air temperature, wind speed and daily duration of bright sunshine were obtained, for the most part from published figures in the *Observatories' Year Book*, or in the *Monthly Weather Report* and *Daily Weather Report*. Some war-time figures which were missing from these sources were obtained directly from Kew Observatory.

From these figures the means of each of the thirty winters, 1919–20 to 1948–49, were computed, winter being defined for this purpose as the seven months, October to April inclusive, which approximates to the normal heating season. In Table I the mean values of each element are listed for each of the thirty heating seasons used. Fig. 1 shows by means of histograms the frequency distribution of each element. The distributions of wind speed and sunshine might be regarded as approximating to the statistical normal, but that of temperature clearly does not, the most striking feature being the almost complete absence of values in the range 43·0° to 43·9°F. It would seem therefore that thirty heating seasons is not really a large enough sample to give a fully representative group of data, but it is probably adequate for the present purpose.

Table II gives a brief analysis of the data. The seasons in which the highest and lowest values occurred are given in brackets alongside the appropriate figures.

The comparable means for the period 1906–35 are, for temperature 44·5°F., and for sunshine 2·57 hr./day. There is no published figure for wind speed. It would appear that the winters of the period 1919–49 did not differ significantly as regards average figures from those of the period 1906–35.

It will be noted from Tables I and II that in this series of heating seasons all the extreme values of the elements have occurred in the last nine seasons. The warmest season of the series (1947–48) followed immediately on the coldest one (1946–47). Examination of the individual winter means shows that there is a tendency for deviations from the overall mean value to be greater in the later seasons. To ascertain whether this tendency was real, the data were divided into three groups, each consisting of ten consecutive seasons, and the standard deviations for each group computed separately. The standard deviations for

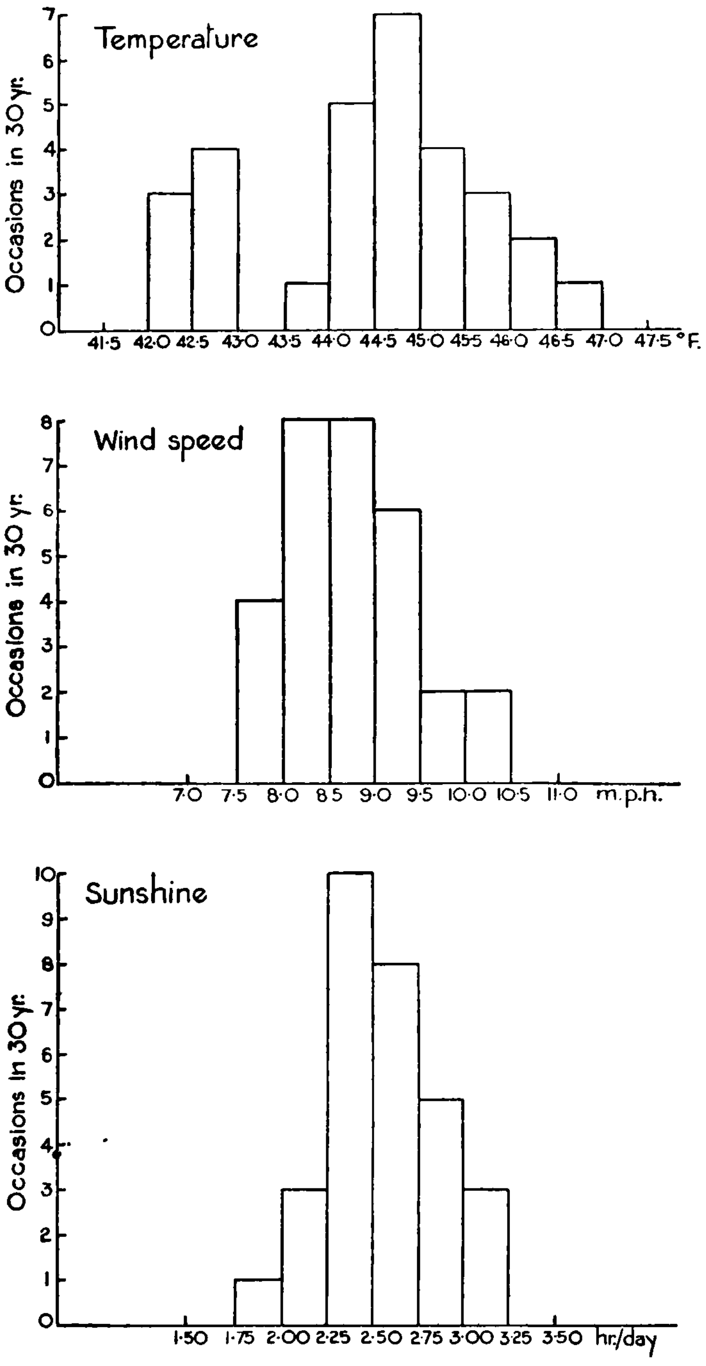


FIG. 1—FREQUENCY DISTRIBUTION OF TEMPERATURE, WIND SPEED AND SUNSHINE AT KEW OBSERVATORY

Period.—30 heating seasons (Oct.–Apr.), 1919–49

all three elements did in fact increase with time, but the increases were not significant, and it is concluded that the changes were not real.

Applying the variances obtained for the three elements over the thirty seasons 1919–20 to 1948–49 to equation (3), we find, for the seasonal heat requirement of the house under consideration, a coefficient of variation of 8·1

TABLE I—MEANS OF AIR TEMPERATURE, WIND SPEED AND DAILY SUNSHINE DURING 30 HEATING SEASONS, 1919–49

Kew Observatory October–April, inclusive.

Season	Temperature	Wind speed	Sunshine
	°F.	m.p.h.	hr./day
1919–20	44·2	8·7	2·41
1920–21	44·2	8·0	2·79
1921–22	44·1	8·6	2·82
1922–23	44·6	7·9	2·32
1923–24	42·3	8·1	2·67
1924–25	45·3	8·4	2·16
1925–26	45·1	8·1	2·42
1926–27	44·7	8·5	2·61
1927–28	44·7	8·8	2·40
1928–29	42·3	7·6	2·78
1929–30	45·1	9·2	2·60
1930–31	44·0	8·7	2·58
1931–32	44·2	8·9	2·36
1932–33	44·8	9·2	3·02
1933–34	42·8	8·0	2·54
1934–35	46·3	8·9	2·19
1935–36	43·7	8·4	2·34
1936–37	44·7	9·3	2·43
1937–38	44·7	9·0	2·79
1938–39	45·6	10·1	3·02
1939–40	42·6	9·5	2·28
1940–41	42·6	10·3	2·26
1941–42	42·8	9·3	2·49
1942–43	46·1	8·1	2·67
1943–44	45·2	7·5	2·12
1944–45	44·6	8·5	2·66
1945–46	45·6	8·0	2·65
1946–47	42·1	9·8	1·99
1947–48	46·7	9·2	2·96
1948–49	45·8	7·8	3·18

per cent. We may say therefore, bearing in mind that some error may be introduced by the fact that the data are not normally distributed about the mean, that in two seasons out of three we may expect that the house will require an amount of fuel within about ±8 per cent. of that used in an average season. The heat requirement in extreme seasons may vary from the mean by about ±15 per cent.

TABLE II—ANALYSIS OF THE DATA FROM 30 HEATING SEASONS, 1919–49

	Temperature	Wind speed	Sunshine
	°F.	m.p.h.	hr./day
Highest value ...	46·7 (1947–48)	10·3 (1940–41)	3·18 (1948–49)
Lowest value	42·1 (1946–47)	7·5 (1943–44)	1·99 (1946–47)
Overall mean ...	44·4	8·7	2·55
Standard deviation ...	1·26	0·72	0·29
Variance	1·59	0·515	0·086

It will be seen that the variance in the heat requirement of the house from season to season due to variations in the weather is very much greater than any error in the estimate of the requirement due to inaccuracies in the equation. In this particular case in fact we may, for all practical purposes, ignore the standard error of estimate of the equation. We may not however be able to do this when dealing with other types of houses, for we cannot always make measurements of temperature and fuel consumption with such precision as was possible in the present case.

It is hoped in due course to extend this analysis to meteorological data from other parts of the country and to other types of houses and heating systems, and so obtain the likely variation in fuel requirements for the whole country from season to season.

* This note is published by permission of the Director of Building Research.

FESTIVAL OF BRITAIN, 1951

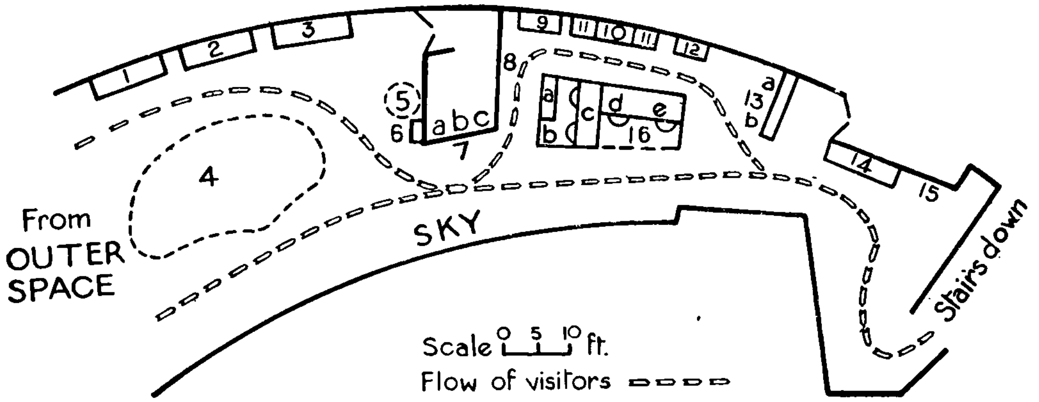
By W. A. L. MARSHALL

Early in 1950 the Festival of Britain authorities asked whether the Meteorological Office would provide a " live " weather forecasting unit to form the main part of the meteorological exhibit in the Dome of Discovery on the South Bank Site, London. It was clear that this was an opportunity of placing before the public some aspects of their weather service on a scale hitherto impossible. The request was approved, and consultations with the Design Research Unit of the Festival began without delay. Proposals by the Meteorological Office on the technical aspects of the exhibit were agreed and implemented by those skilled in the art of modern presentation. At the same time ideas by the designers—which would probably not have been included in an exhibit designed exclusively by meteorologists—were accepted in the Festival spirit. Arrangements were also made with His Majesty's Stationery Office for a *Souvenir Weather Report and Forecast* to be prepared, reproduced and sold to the public in the Dome. Relations between all those engaged in the work of the exhibit were of the happiest character, and although all the items were not in position on the opening day, May 4, 1951, the exhibit was sufficiently complete to do justice to the large amount of work involved and, it is hoped, to the Meteorological Office.

Meteorology has been given a prominent and generous amount of space in the section of the Dome relating to Inner Space. The exhibit is arranged in a broad sweep along the top balcony—appropriately named Sky—and is connected by ionospheric and radio exhibits to Outer Space, dealing with astronomy. Incidentally the view from the balcony is one of the most striking in the whole of the Dome, and is a favourite point at which visitors stop to admire the brilliant panorama made by other galleries and the ground-floor exhibits set out before them.

The general lay-out of the meteorological section is shown in the plan. As a gesture to modernity, the designers included a decorative model of the sun as the source of life, worked in plastic and metal, and forming part of the panel relating to "The earth's atmosphere". This panel, painted in striking shades of blue, gives a straightforward picture of the height in the atmosphere at which weather phenomena occur, and indicates the heights to which aircraft, balloons, radio-sondes and rockets have ascended. Another panel devoted to " Seasonal weather " contains an artist's conception of the development of nature through the seasons from the delicate green leaves of spring to ripe autumnal fruit; it is edged by zodiacal signs with a snow-flake at the base! The whole frieze illustrates the gradual change from the dullness of January, the snow of February, the increasing brightness of spring and summer to the mellow shades of autumn and eventual return to chilly winter. The "Maypole scene ", for instance, is charming.

A thematic display model symbolizing sunshine, rain and clouds contrasts effectively with the orthodoxy of illuminated rainfall and sunshine charts and cloud-form transparencies in the " Climatological panel " which, appropriately, pays a tribute to the five thousand voluntary observers throughout the country to whom climatology owes so much. In the middle of the balcony, set out on a green background, is a comprehensive and well captioned display of instruments.



METEOROLOGICAL SECTION OF THE DOME OF DISCOVERY

1. The earth's atmosphere
2. Seasonal weather
3. Climatology and clouds
4. Meteorological instruments
5. Tempest prognosticator, 1851
6. Weather report, 1851
7. Collection of weather reports
    a. Collection by W/T
    b. Collection by teleprinter
    c. Synoptic reporting stations in the British Isles
8. Weather reporting by teleprinter
9. Reports from ships at sea
10. Weather Quiz
11. Weather on the move
12. Special forecasts and climatological information
13. Upper air
    a. Upper winds over the world
    b. Radio-sondes and radar
14. Thunderstorm location
15. Cloud scape
16. Forecasting unit
    a. Teleprinters
    b. Sale of Souvenir Report
    c. Charting benches
    d. Preparation of Souvenir Report
    e. Forecaster

Meteorological links with the Great Exhibition of 1851 are the replica of Dr. Merryweather's Tempest Prognosticator and a copy of the first *Daily Weather Report* to be produced and sold to the public. Dr. Merryweather, of Whitby, claimed that leeches contained in glass jars would climb into the necks of the bottles when a thunderstorm was pending; a small piece of whalebone concealed in the neck of each bottle was thus dislodged, releasing a chain which rang a bell. The leeches on display are dummies, so there has been no opportunity of checking the efficiency of the apparatus! However, it draws a smile from even the most cynical critic of modern forecasting.

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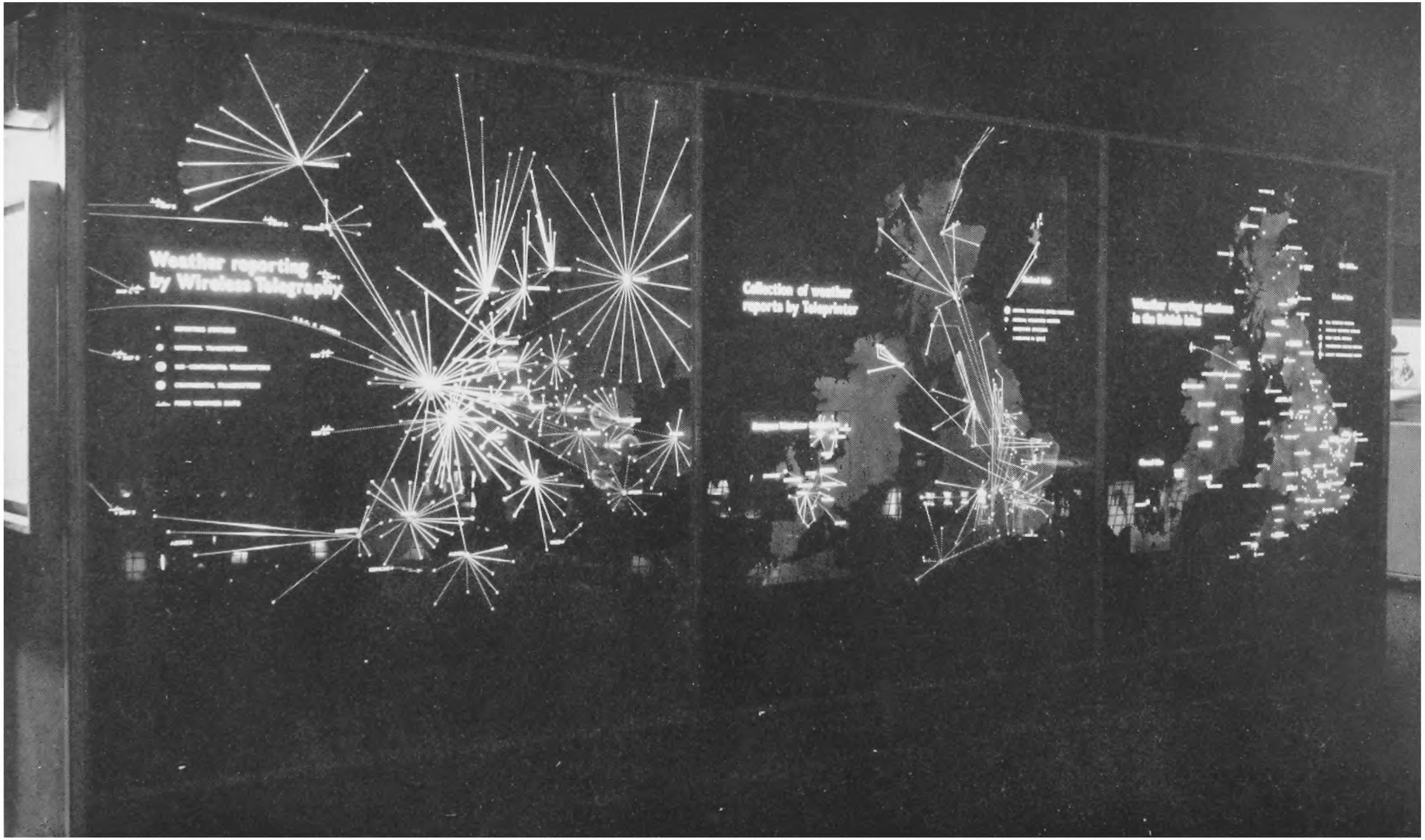
GENERAL VIEW OF THE METEOROLOGICAL SECTION OF THE DOME OF DISCOVERY


Weather reporting by Wireless Telegraphy
Collection of weather reports by Teleprinter
Weather reporting stations in the British Isles

DIAGRAMS ILLUSTRATING THE COLLECTION OF WEATHER REPORTS IN THE DOME OF DISCOVERY

FORECASTING UNIT AT THE DOME OF DISCOVERY

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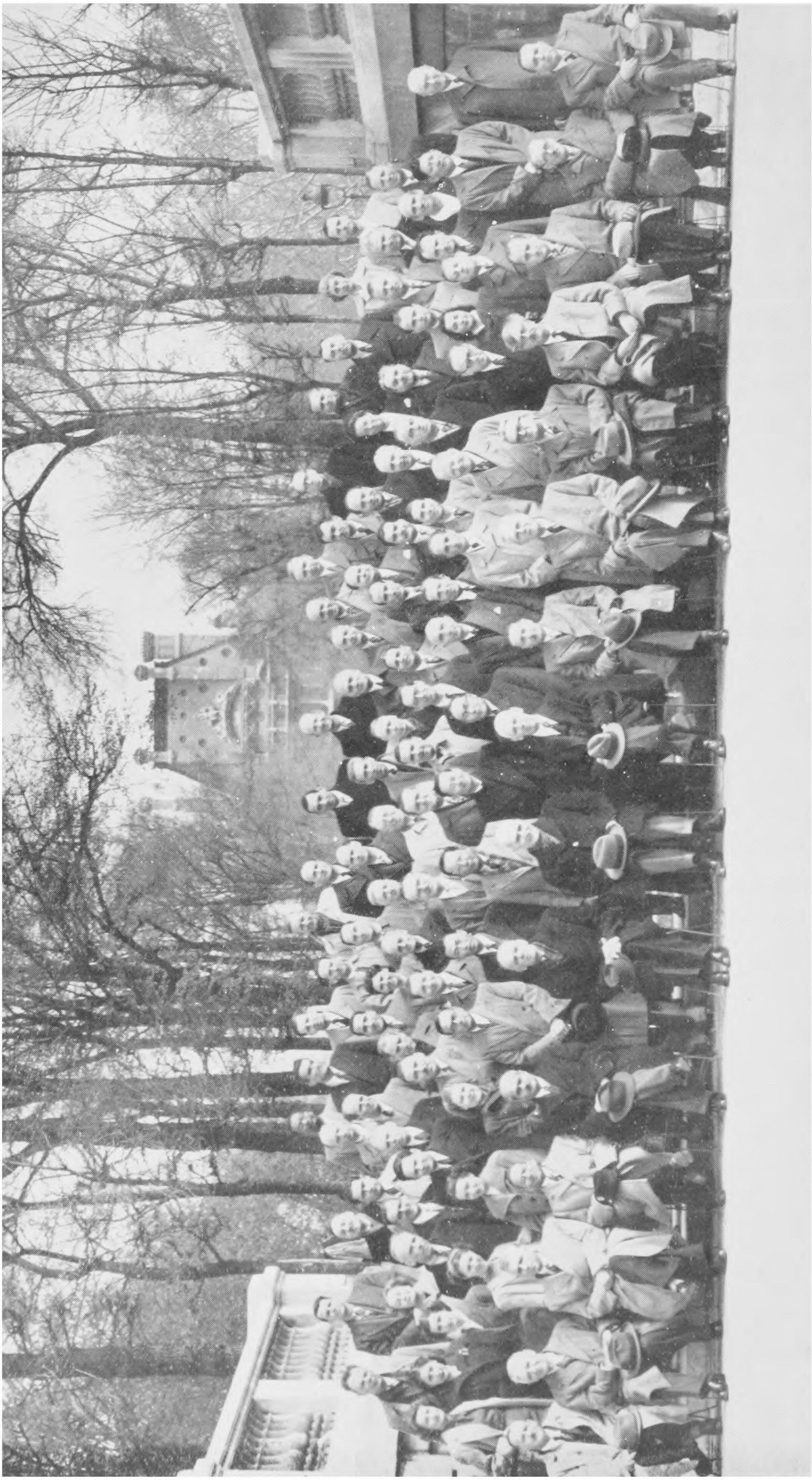


CONGRESS OF THE WORLD METEOROLOGICAL ORGANIZATION, PARIS, 1951

Reproduced by courtesy of La Météorologie Nationale, Paris

Leading to the forecasting unit are three beautiful glass charts each 8 ft. × 6 ft. illuminated in red, white, blue and green on a black and grey background, which form the most effective inanimate exhibits in the Sky section of the Dome. Few of the tens of thousands who pass this point each day fail to stop, examine and admire them; the directors of Commonwealth and foreign meteorological services fresh from the Conference of the World Meteorological Organization, who were passing through London at the time the Festival was opened, were particularly impressed with this display. The first chart summarizes the highly organized international exchange of weather reports by wireless telegraphy; observing stations on land and sea are shown connected to their national headquarters and the functions of national, sub-continental and continental transmitting stations—Dunstable in the case of Europe—are depicted in a colourful manner understandable at a glance. The middle chart features the elaborate British meteorological teleprinter networks, with lines radiating from Dunstable not only to all parts of the British Isles but to places as far away as Norway, Finland, Germany, Italy and France. The third chart shows the position of all weather reporting stations in the British Isles: full synoptic stations (with place names) in red, auxiliary stations in green, radio-sonde stations in white and thunderstorm-locating stations in a rich blue; prominence is given to the one remaining meteorological reconnaissance flight over the Atlantic Ocean. The complete panel is a mass of colour visible from the opposite side of the 365-ft. Dome.

Just around the corner the eye is immediately caught by the words " Weather reporting by teleprinter ", shining, as it were, through large teleprinter keys mounted on isobaric patterns cut into the wall. Teleprinter tapes connect a cluster of illuminated reporting stations to their collecting centre. Legends describe the collection and broadcasting of reports by teleprinter, while suitable symbols representing the interception of wireless broadcasts from foreign capitals give exciting emphasis to the importance of the Central Forecasting Office at Dunstable as a hub of meteorological communications.

Then there is a panel devoted to weather reporting from ships at sea. It contains an elegant model of one of our own weather ships. Photographs of some of the activities aboard them are supplemented by a caption acknowledging the services of voluntary observers in merchant ships of all nations, whilst a coloured transparent map shows the method of collecting the vital reports from shipping routes throughout the world.

Push buttons that work have an unfailing attraction. Such an attraction is afforded by the " Weather Quiz " in which a full weather report, as plotted on a forecaster's weather chart, is prominently displayed in red and blue on an illuminated glass screen. To the layman it is at first merely a collection of unintelligible symbols grouped around a central circle. But for every symbol contained in the plotted report there is a similar symbol ranged along the bottom of the exhibit. To find out what, for example, the " two black dots" signify the visitor presses the appropriate button and the words " intermittent moderate rain " flash on the glass screen before him, and so on, through all the 18 items of which the full weather report is composed.

Another panel entitled " Weather on the move " shows a weather map of the Atlantic Ocean and Europe with a deep depression centred near Iceland and a well marked trailing cold front along which very active secondaries subsequently developed. Transparencies provide an interesting series of charts at 12-hr. intervals showing the rapidity with which depressions can form and move and thus how tomorrow's weather may depend on changes taking place today thousands of miles away.

The uses to which special forecasts and climatological information are put are presented very attractively in pictorial form. Pride of place is given to agriculture, but industry, transport, aviation, public utilities and sport are all indicated. The racing pigeon appears to be rather surprised and somewhat uncomfortable at his inclusion, but he typifies the continually widening range of activities served by the Meteorological Office.

The visitor now reaches the " Upper air section ". The important work of British meteorologists on upper winds over the world is shown in an illuminated push-button model; and a radio-sonde exhibit, surmounted by an inflated balloon reaching the roof of the Dome, demonstrates, together with a small radar panel, recent means of improving meteorological knowledge and forecasting technique. Nearby is a " sferic " display prepared by the National Physical Laboratory; illuminated arrows from two stations point towards a lightning symbol which appears intermittently in continually changing positions, thus showing the simple principle of direction finding. The latest " sferic " set with its many knobs and flashing cathode-ray tube, and a plotting table as used when all four British thunderstorm-locating stations are making simultaneous observations, round off the upper air display.

It might be said that more prominence should have been given to meteorological research. Unfortunately fundamental meteorology does not lend itself readily to presentation in a form suitable for exhibition purposes. However, the Duty Forecaster at the forecasting unit is able to enlighten those who are particularly interested in the more specialized work of the Office.

Finally, a few words about the centre piece of the Meteorological Office display—the " Weather forecasting unit ". Reception of both main and second channel teleprinter broadcasts from the Central Forecasting Office at Dunstable ensures a continuous flow of weather reports from Spitsbergen to north Africa and from the Urals to Canada. Practising forecasters are sometimes apt to look on the rapid collection and dissemination of weather reports as commonplace, but Festival visitors are fascinated to see reports from a weather ship in mid Atlantic being received in the Dome ten minutes after the observations were made. The organization displayed on the walls around them comes to life as they see weather reports come in from some 150 British reporting stations and many places on the Continent within about half-an-hour of the time of observation, and from the far ends of the Atlantic, Greenland, Europe and western Russia within an hour or so. Crowds gather several deep for hours on end to see the two Scientific Assistants entering the observations so quickly and neatly on the charts—and it is not only small boys who are intrigued by the expert manipulation of two pens bound together to facilitate plotting in two colours. Every day scores of visitors from home and abroad are supplied on request with the latest weather at their home town with, to the inquirers, surprising detail and promptitude. Even a Philadelphian visitor was served in a couple of minutes after consultation with Dunstable on the direct telephone tie-line.

The Duty Forecaster is occupied with an almost continuous barrage of questions—some frivolous, but mostly serious. He has to discuss everything ranging from existing and future weather to climatology, the technicalities of radiosondes and thunderstorm locating, or the activities of the Meteorological Office as a whole. Moreover, he has to frame his replies in the manner best suited to meet the comprehension of the inquirer. Concurrently, the forecaster supervises the preparation of the *Souvenir Weather Report and Forecast.* This has an attractively designed cover in red and green embodying the Festival of Britain and Meteorological Office badges, a foolscap weather chart inside and an explanation on the back. It is issued twice daily. The morning report, available for sale at 10.30 a.m. (except on Sundays), contains a chart of the weather over north-west Europe at 0600 G.M.T. together with a general forecast for the whole country and a detailed forecast for the " London area " until midnight supplied by the Central Forecasting Office. The afternoon report, on sale at 3 p.m., contains a chart for 1200 G.M.T. and forecasts for the following day. Prepared in two colours by a Meteorological Office draughtswoman in full view of the public, the report is reproduced and sold on the spot at 3*d.* each by staff of His Majesty's Stationery Office who are attached to the forecasting unit. It is a measure of the popularity of this feature that 21,000 copies were sold in the first fortnight. It is fitting that the Stationery Office and Meteorological Office, who have produced so many valuable contributions to meteorology between them over the years, should be associated together in this commemorative venture.

If the mere number of visitors is any criterion, the success of the Meteorological Office contribution to the Festival of Britain 1951 is already assured. Its ultimate value is more difficult to assess. The large numbers of searching questions from visitors of all classes suggest an increasing desire for more background knowledge on meteorology in general and weather forecasting in particular. The results must be of educational value, and should lead to a more intelligent use of the weather information made available to the public through radio, television and the Press.

METEOROLOGICAL OFFICE DISCUSSION

Vorticity in dynamical meteorology

The Discussion of March 12, 1951, was devoted to consideration of the significance of vorticity in dynamical meteorology. Mr. J. S. Sawyer opened the discussion.

In his introduction Mr. Sawyer described the hydrodynamical concepts of vorticity and circulation. Vorticity can be regarded as the average angular velocity of a small fluid element, and circulation round a closed curve is the integral of the average normal component of vorticity over any area bounded by the curve. Under certain restrictive conditions, the circulation has the important property that it remains constant round any closed curve which moves with the fluid. The most important of these restrictions is that the density of the fluid should be a function of pressure only, and although this condition is not satisfied in the atmosphere the direct effect of density gradients on changes of the horizontal circulation is usually small and can be ignored.

The rotation of the earth is another important factor which must be introduced into simple hydrodynamical theory before it can be applied to the atmosphere. By expressing the condition for the constancy of circulation in the atmosphere in terms of co-ordinates with respect to axes moving with the earth instead of with respect to axes fixed in space, some of the basic equations of meteorological dynamics may be derived. Of these the most important is the so-called "vorticity equation", which may be written,

$$\mathrm{div}_z\,\mathbf{V} = -\frac{1}{\zeta + l}\frac{d}{dt}(\zeta + l) \qquad \ldots (1)$$

where $\mathrm{div}_z\,\mathbf{V}$ is the horizontal divergence of velocity, ζ is the vertical component of vorticity (i.e. the vorticity of the horizontal motion), l is the Coriolis parameter and d/dt denotes differentiation following the fluid motion. Several approximations enter into this equation but it appears to describe the main features of the large-scale horizontal motions of the atmosphere.

Synoptic studies of atmospheric motion in large-scale features such as depressions and anticyclones have shown that the horizontal convergence in the lower troposphere is usually largely balanced by divergence at a level near the tropopause, and that divergence near the ground is associated with convergence aloft. There must be some intermediate level at which the divergence is zero, but this is not necessarily the same everywhere; however, some American authors have attempted to identify it with the 500- or 600-mb. levels.

The vorticity equation (1) has two important applications. First, if applied to the level of non-divergence where $\mathrm{div}_z\mathbf{V}=0$, it shows that the vertical component of absolute vorticity, $\zeta+l$, is constant following the fluid motion. As a consequence of the increase of the Coriolis parameter, l, northwards, it follows that at the level of non-divergence the vorticity of northward moving air must decrease relative to the earth — become more anticyclonic — and the vorticity of southward moving air must decrease — become more cyclonic. In a series of troughs and ridges superimposed on a westerly air stream it is possible for the decrease of vorticity from trough to ridge to be just balanced by the increase of the Coriolis parameter northward. The troughs and ridges can then be stationary. This defines Rossby's stationary wave-length which varies with latitude and wind velocity from 40 to 120 degrees of longitude.

On the other hand the vorticity equation (1) can be used to measure the divergence, and this is probably its most important application. It seems likely that geostrophic winds can give an adequate approximation to the vorticity, and thus a knowledge of the changes of the geostrophic wind (or the pressure field) can lead through equation (1) to a knowledge of the divergence. The divergence is of vital importance in synoptic meteorology because of its direct connexion with vertical air movements and rainfall, but the divergence cannot be estimated directly from geostrophic winds because it depends essentially upon geostrophic departures. The vorticity equation provides a way round this difficulty.

Use of the vorticity equation applied to two levels together with the hydrostatic equation has led Dr. R. C. Sutcliffe to formulate a very useful expression for the relative divergence, i.e. the difference between the divergence at the two levels. It is a valuable measure of cyclonic development and can be written

$$-\frac{V'}{l}\frac{\partial}{\partial s}(l + \zeta' + 2\zeta_0)$$

where V' is the thermal wind speed, ζ' is the vorticity of the thermal wind field, ζ_0 is the vorticity of the geostrophic wind field at some low level in the troposphere, l is the Coriolis parameter and $\partial/\partial s$ denotes differentiation following the fluid motion.

Mr. Sawyer went on to explain how vorticity could be estimated from isobaric charts on the basis of the geostrophic assumption, and he illustrated this with a series of charts (one of which is reproduced as Fig. 1). Vorticity is most conveniently evaluated by means of a small scale engraved on transparent material in the form shown in Fig. 2 and placed on a chart of the contours of the isobaric surface appropriate to the level considered. In latitude 50° it is

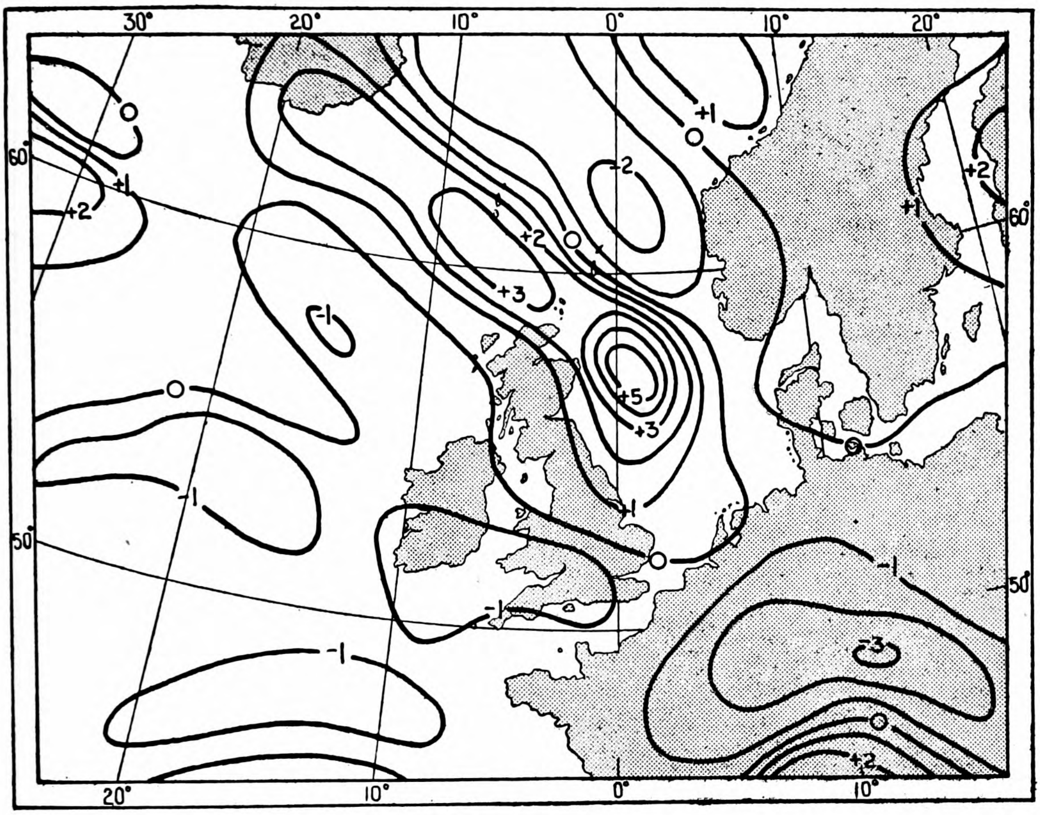
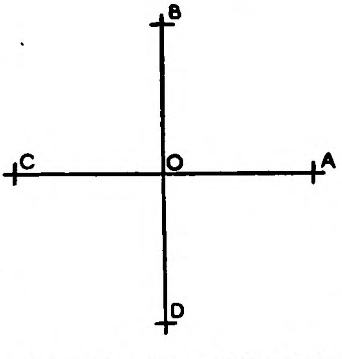


FIG. 1—RELATIVE VORTICITY AT 1000-MB. LEVEL, 0300 G.M.T., MARCH 16, 1949
Units: 10^{-1} hr.$^{-1}$



OA = OB = OC = OD = 168 nautical miles

FIG. 2—SCALE USED FOR ESTIMATING VORTICITY

convenient to use a map distance of 168 nautical miles between each point A, B, C and D and the centre O. If the height of the isobaric surface is then read off the chart at A, B, C, D and O in units of 100 ft. and denoted by h_A,h_B, etc., the vorticity of the horizontal motion is then given in units of one every ten hours (10^{-1} hr.$^{-1}$) by the expression,

$$h_A + h_B + h_C + h_D - 4h_O$$

The expressions of the form $V'\partial\zeta_0/\partial s$ arising in Sutcliffe's expression for development can also be evaluated by a similar simple process.

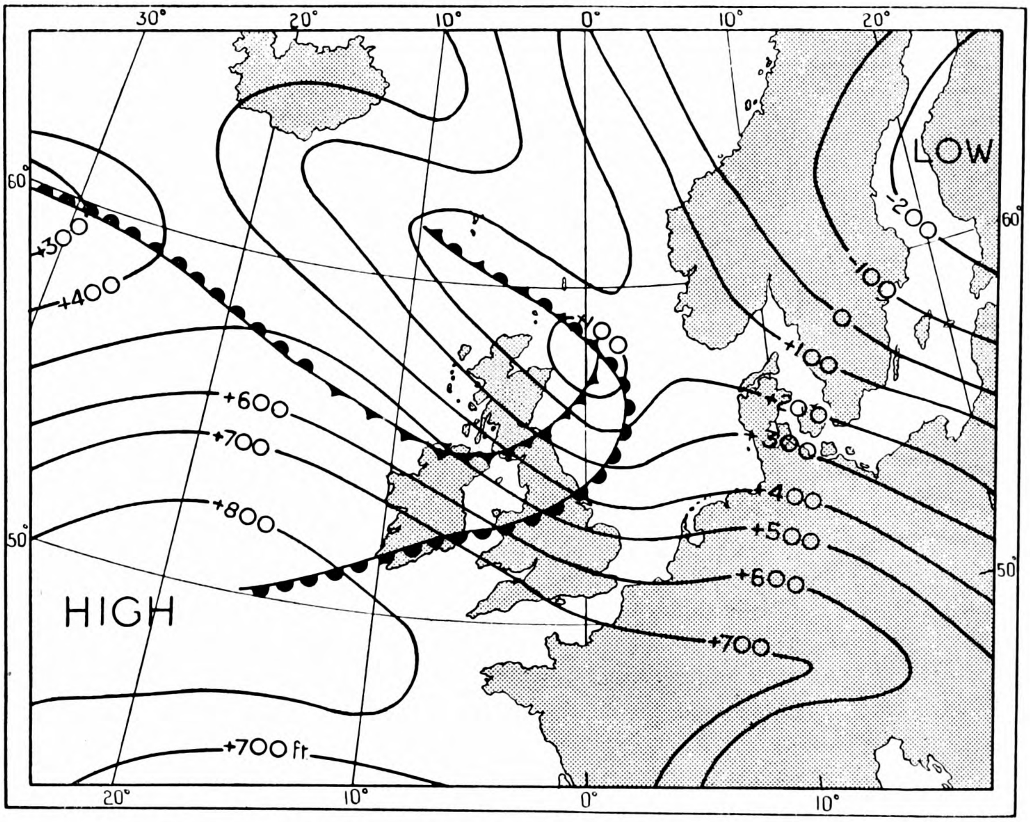


FIG.3—1000-MB. CONTOURS, 0300 G.M.T., MARCH 16, 1949
This chart is used in estimating the vorticity for Fig. 1

In the discussion which followed several speakers expressed some doubt as to whether upper air charts were sufficiently accurate to permit calculations of vorticity and vorticity gradients to be carried out with the required accuracy.

Mr. Briggs also drew attention to the omission of the ageostrophic wind and to the fact that the very high values of vorticity at frontal surfaces were necessarily smoothed out in these computations. Mr. Sawyer, in reply, admitted that the errors were considerable, but experience of working with vorticity charts suggested that values were probably accurate to something like 30 per cent., and the agreement between calculated development and rainfall areas suggested that the computations were physically sound and meaningful.

Dr. Scorer drew attention to some of the theoretical approximations in the theoretical treatment of vorticity. He said that vorticity would not be strictly conserved at a level of non-divergence because of the advection of vorticity from levels above and below by vertical air movements.

Mr. Hurst pointed out that as yet vorticity charts had no direct numerical application to forecasting. Mr. Sawyer agreed, pointing out that the calculations of development and rainfall applied to the time of the chart on which the calculations were based, and gave results which could only confirm existing observations of rainfall and pressure tendency. The important problem of integrating with respect to time had not been tackled yet, although assessment of future development was made by inspection of charts in relation to Sutcliffe's development expression.

Mr. Bannon mentioned the possible use of the Bjerknes circulation theorem as a tool to study the vertical circulations in jet streams, but Mr. Sawyer pointed to the need for caution in studying changes in the horizontal components of vorticity; these are dependent on departures of wind from geostrophic.

Mr. Dight asked whether vorticity theory would throw any light on surges of pressure which affected simultaneously areas of several thousand square miles in extent. Mr. Sawyer was doubtful.

Mr. Gold remarked that, although the subject was vorticity, little had been said about vortices. He referred to earlier work which showed that two co-existent vortices must rotate about one another. He also said that if the study of vorticity could explain obscure dynamical changes, it was a valuable contribution to our knowledge even though its application to forecasting was not immediate.

Mr. Matthewman demonstrated the practical procedure of drawing charts of development and the use of isopleths of the sum of the heights of the 500-mb. and 1000-mb. surfaces to simplify the process.

Mr. Bushby[1] mentioned the numerical calculations of vertical velocities which had been made at the Central Forecasting Office by the application of relaxation methods to the solution of a differential equation involving the horizontal field of development.

Dr. Sutcliffe was sceptical about the use of a level of non-divergence. On the other hand the horizontal divergence was one of the most important parameters in atmospheric motion on the synoptic scale. It was not easy to evaluate directly from wind observations and it was fortunate that the vorticity equation provided another approach to the problem—it was not likely that any other simpler and more practical parameters would be derived from the equations of atmospheric motion.

REFERENCE

1. BUSHBY, F. H.; Relaxation methods and their application to meteorological problems. *Met. Mag., London,* **80**, 1951, p. 71.

METEOROLOGICAL RESEARCH COMMITTEE

The 15th Meeting of the Physical Sub-Committee was held on April 6. Dr. T. W. Wormell has now joined this Sub-Committee.

The problem of the formation of radiation fog is acquiring increasing importance and the Sub-Committee considered some detailed proposals for research to assist the forecaster in dealing with it.

Various aspects of turbulence were represented by four widely different papers, a paper[1] on severe clear-air turbulence at high altitude on November 2 and 7, 1950, by Mr. J. K. Bannon, a paper[2] by Mr. R. F. Jones dealing with the track of thunderstorms on June 5, 1950, as seen by radar, a paper[3] on the effect of a hedge on the flow of air by Mr. N. E. Rider and a note[4] by Mr. A. C. Best on the effect of turbulence on drop-size distribution in cloud.

Mr. Murgatroyd presented the results of a re-analysis of some anomalous sound-reception experiments[5] and other papers considered included one on the evaporation of raindrops[6] and one on the occurrence of high rates of ice accretion on aircraft[7].

The 11th Meeting of the Instruments Sub-Committee was held on April 26, 1951. Progress made with the development of a searchlight method for investigating the upper atmosphere was reviewed, and it was decided to concentrate effort on the two-station technique for the present.

The Committee considered the possible uses of the vortex-tube thermometer and it was decided to seek further information concerning this instrument.

Consideration was also given to the possibility that there might be a dynamical explanation of the apparent diurnal variation of temperature in the upper air.

[1] *Met. Res. Pap. ,London,* No. 631, 1951

[2] *Met. Res. Pap., London,* No. 613, 1951

[3] *Met. Res. Pap., London,* No. 602, 1951

[4] *Met. Res. Pap., London,* No. 627, 1951

[5] *Met. Res. Pap., London,* No. 611, 1951

[6] *Met. Res. Pap., London,* No. 603, 1951

[7] *Met. Res. Pap., London,* No. 610, 1951

NOTES AND NEWS

Meteoros

We welcome the appearance of the first number of the new quarterly journal *Meteoros* (Year 1, No. 1, January 1951), published by the National Meteorological Service of the Argentine. The first number contains 120 pages, 9¾ in. × 7 in.

The main articles in the first number deal with the application of Thornthwaite's climatic classification to the Argentine, statistical methods of medium-range forecasting of the temperature at Buenos Aires, variations in the annual rainfall of the Argentine, errors in measurements of height by barometer ascribed to irregular fluctuations of pressure, the effects of climate on the flowering of the peach, forecasting the floods of the Paraná River, and the optimum temperature for human beings. The articles are all in Spanish with summaries in Spanish and either English or French.

In addition to the major articles, there is a brief history and summary of present activity of the National Meteorological Service, notes on current events such as the first Congress of the World Meteorological Organization, and reviews.

REVIEW

The atmospheres of the earth and planets. Edited by Gerard P. Kuiper. 9½ in. × 7 in., pp. viii+366. *Illus.* University of Chicago Press, Chicago, Ill., 1949, Cambridge University Press, London, and W. J. Gage & Co., Ltd., Toronto. Price: $7.50 or 56*s.* 6*d.*

This book is composed of contributions from several authors on the atmospheres of the earth and planets, presented at the Fiftieth Anniversary Symposium of the Yerkes Observatory in September 1947, sponsored by the University of Chicago.

For the meteorologist the book starts off on familiar ground with an exposition of the pattern of atmospheric circulation by Rossby in which the new concept of the jet stream (new in 1947) is fitted into the circulation and energy- exchange processes of the atmosphere. However, the reader is soon moved off into the dimly defined border regions where meteorology merges into other sciences and which are normally familiar only to the specialist. Nevertheless the meteorologist need not fear that his time is not well spent in covering these regions as there he will find new and exciting subjects which have developed greatly in the last few years.

The larger part of the subject matter is covered by articles by Van de Hulst on the scattering and polarization of light (including ultra-violet and infra-red) in the atmosphere, and by P. Swings on the spectrographic analysis of the light from the night sky and the aurora. Van de Hulst deals with most aspects of the behaviour of light in the atmosphere. Starting from the deductions from Mie's equations, he explains the optical phenomena of the atmosphere, which serve as experimental checks on the theory. The discussion however is not confined to the earth's atmosphere but planetary atmospheres also are brought in. Of particular value are the references to the problem of secondary scattering and the ways of calculating its effect, and also to a suggested approximate method based on an empirical rule by Lyot of circumventing the problem of multiple scattering which should interest the instrumentalists. An extensive bibliography of 129 references is provided. Van de Hulst's article is matched by that of P. Swings who treats the subject of the spectra of the night sky and the aurora. This is still a young subject and there is much which is still unknown; however, great progress has been made in determining the origin of the light of the night sky. Fully a third of this light arises in our own atmosphere and is explained as coming from changes in molecular states, at very high altitudes, including the so-called " forbidden " transitions and transitions from metastable states in three particle collisions. Various theories to explain these transitions are outlined, including those of Chapman, Bates, and Nicolet.

There are several articles on the attack on the upper atmosphere by the aid of V-2 rockets in New Mexico, most of which information has appeared in report form elsewhere. Although the solution of some problems will depend on observations taken outside our atmosphere from rockets, one nevertheless cannot help contrasting the expense and complication of this line of attack with the simplicity of the methods of spectrographic analysis and to compare the results in both cases, with the balance heavily in favour of the simpler method. The comparison should give heart to the individual or to the small group of workers eager to make some real contribution to the knowledge of the upper atmosphere but possessed of limited means.

In other chapters Whipple's method of atmospheric-density measurement by observations on meteor velocities and decelerations is described, and the results are analysed to show the seasonal density variations. Spitzer discusses the atmosphere above 300 Km., and there are interesting articles on the origin and composition of the atmospheres of the earth and the planets, including the results of the Mount Wilson observations presented by Theodore Dunham Jr., and an article by Gerald P. Kuiper, the author. The book concludes with a short article on the laboratory work on absorption spectra and a discussion on the possibilities of plant life on Mars.

Although, for the most part this book touches only the fringes of what is usually understood as meteorology, it is recommended to the meteorologist as a comprehensive summary of knowledge in fields adjacent to his own from which he will draw useful ideas.

D. D. CLARK

HONOURS

The Birthday Honours List 1951 announced the award to Dr. R. Frith of the O.B.E. Dr. Frith, now Head of the Instrument Research (General) Branch, was for four years in charge of the Meteorological Research Flight. There must have been few flying men who made so many visits to the stratosphere during those four years, for his flying hours amounted to about 700 and many of the flights were devoted to measurements in the stratosphere and higher troposphere.

Members of the Meteorological Office will be specially interested in two other names which appear in the same Honours List. The first is that of Dr. G. M. B. Dobson, F.R.S., once for a short time on the staff of the Office, Chairman of the Meteorological Research Committee for the last four years and first Chairman of the Physical Sub-Committee. Dr. Dobson receives the C.B.E.

Another is Dr. W. R. G. Atkins, F.R.S., of the Marine Biological Laboratory, Plymouth. Dr. Atkins, who also receives the C.B.E., held a temporary appointment in the Meteorological Office, Instruments Division, during the war, when he was engaged on research on visibility.

OBITUARY

Mr. K. J. Pitt.—It was with great regret that we learned of the death of Mr. Kenneth James Pitt on May 30, at the early age of 31, after about two months' illness.

Mr. Pitt joined the Office at the beginning of the war as a temporary Assistant III and was successful in the Civil Service competition for established appointment as Assistant Experimental Officer in 1947. He was promoted Experimental Officer about six months before his death.

Soon after his release from the forces, in which he had served as a Flying Officer in the Meteorological Branch of the R.A.F.V.R., Mr. Pitt spent a little more than a year in the forecasting section at Victory House, and was then posted for a three-year tour in the Middle East from which he returned in December 1950.

Mr. Pitt's early death has deprived the Office of a capable forecaster and his fellow officers of a trusted colleague. To his wife and three young children we offer our deepest sympathy.

METEOROLOGICAL OFFICE NEWS

Colonial Meteorological Service.—The Office continues to assist the Colonial Meteorological Service by releasing staff to the Colonies. Mr. J. E. Stevens has been appointed the senior meteorological officer in the newly formed Meteorological Service of Northern Rhodesia. Four assistants, namely Messrs. G. A. Freeman, A. F. Gray, P. Howarth and R. A. Parsley have followed Mr. Stevens to Northern Rhodesia.

The British West African Meteorological Service has recently established a radio-sonde/radar wind station in Nigeria, and for that the Office has released a radio (meteorological) mechanic, Mr. W. Paton. The post of radio-sonde officer is being filled by Mr. G. Y. Benzies who served in the Office during the war.

Retirement.—Dr. Harold Jameson retired from the Meteorological Office on May 31, 1951, after serving 11 years in the Marine Branch.

Dr. Jameson spent the greater part of his working life in Colombo Observatory of which he became Director in 1932.

He retired from the Colonial Service towards the end of 1939 and returned to England. During his service in Ceylon he received first his M.Sc. and later his D.Sc. degree for published papers on the climatology of Ceylon. These papers covered a wide field, particularly concerning the rainfall in the island.

Dr. Jameson's arrival back in England coincided closely with the outbreak of the late war and he was not left long in retirement, for in February 1940 he volunteered for service with the Meteorological Office and was posted to the Marine Branch which had then taken up its war-time location at Stonehouse, Glos. Dr. Jameson came to the Branch at a time when incessant calls were being made for the solution of marine meteorological problems. With his great experience of handling and working up statistical data his services were invaluable in producing meteorological atlases covering all oceans of the world, work entailing the analysis of over 5,000,000 sets of observations including all meteorological elements. While at Stonehouse Dr. Jameson also served in the Home Guard. On the return of the Branch to London in 1945 he continued his service and has carried out research which includes the investigation of the diurnal variation of barometric pressure within tropical seas and within the Mediterranean Sea, the diurnal variation of fog at sea, and the relation between wind and pressure gradient over the oceans.

Of a very retiring and kindly disposition Dr. Jameson took a keen interest in the junior staff of the Branch, and was at all times ready to assist them in their study of meteorology and many are indebted to him for his patient help in this respect.

As a small parting gift his shipmates in the Marine Branch presented him with an inscribed barograph, so that while in retirement he can pursue his studies of diurnal range of barometric pressure.

In bidding farewell to "Jamey" as he was affectionately known we wish him good health and happiness in a well earned retirement.

Resignation.—Many members of the Office will learn with regret of the resignation of Mr. H. J. Ferrer. Mr. Ferrer joined the Office as a radar expert in 1943, and has specialized in the application of electronic techniques to meteorological equipment. He played a leading part in the adaptation of a war-time army radar set, the GL. III, for wind measurement and the development of the nylon mesh targets. He left to take up an appointment with a firm which makes radio-sonde equipment. He takes with him the good wishes of all his former colleagues in the Instruments Division and at many outstations.

Mr. H. E. Carter, who retired from the Office on August 31, has been appointed by the Crown Agents for the Colonies to work up the climatological records of the Falkland Islands Dependencies Survey for years up to 1950. He is working in the Meteorological Office at Harrow.

Dramatic Society at Harrow.—The Meteorological Office at Harrow has formed an amateur dramatic society which has been christened the " New Meteor Players ". Their first production " On Monday Next ", a comedy by Philip King, which was presented on a home-made stage in the Canteen gave considerable pleasure to a full house and was, incidentally, a financial success.

Sports and Athletics.—*Harrow.*—The second annual athletic meeting of the Harrow Meteorological Office Social and Sports Club was held at Headstone Manor Recreation Ground on the evening of May 30.

The championship events, inaugurated at the first meeting last year, were won by R. J. Garner, Binbrook (100 yd., men), Miss K. N. Newman, Training School (100 yd., ladies), W. Lawson, Leeming (440 yd. and 880 yd.). Outstations won the men's relay and Victory House the ladies' relay.

The Harrow Meteorological Office was divided into two teams, the Climatological Division and the rest, which competed for points in most of the events. The Climatological Division won by the narrow margin of 3 points, the scores being 40–37.

Mrs. F. J. Scrase kindly presented the medals and certificates.

WEATHER OF APRIL 1951

Mean pressure was above 1015 mb. over central Europe, the Mediterranean and most of the North Atlantic, while it was 1020 mb. or above, over Greenland; these pressures were about 2 to 6 mb. above the normal. Mean pressures over west Africa were generally between 1010 and 1015 mb. Mean pressure was below 1010 mb. over Scandinavia, about 4 mb. below normal.

Mean temperatures were in the neighbourhood of 50°F. over central Europe, about normal for April, but over the British Isles where mean temperatures were between 40° and 45°F. they were about 4°F. below normal.

In the British Isles cool, unsettled weather prevailed during the first half of the month and again from the 26th to the end. Snow or sleet showers were frequent, particularly in Scotland. Broadly speaking rainfall considerably exceeded the average over most of Great Britain but was less than the average in Ireland, while sunshine exceeded the average generally.

On the 1st a depression to the west of Scotland moved south-south-east and then turned east across northern England causing general rainfall in England and Wales and scattered rain in Scotland and Northern Ireland. From the 2nd to the 5th a depression south-west of Iceland moved east to the west of Norway, while troughs or secondary depressions crossed the British Isles; rain fell generally on the 3rd, heavy in the west, while rain or showers occurred on the 4th (2·50 in. at Borrowdale, Cumberland, 2·28 in. at Glen Etive, Argyll and 2·16 in. at Carbost, Skye on the 3rd). On the 6th another depression south of Iceland moved south-south-east to our south-west coasts, while a secondary off south-west Ireland moved east-north-east over England and, on the 7th, the main depression moved east-north-east over southern England. Rain was general on the 6th, and rain, sleet or snow occurred on the 7th, while thunderstorms occurred locally in south-east England on the 7th. Thereafter another depression west of Scotland moved south-east to England and a secondary moved quickly across southern England to Denmark; fairly heavy rainfall was registered in the south of England on the 8th and 9th and wintry showers were widespread on the 10th. Subsequently a deep depression south of Iceland moved to south-west Norway, while troughs crossed the British Isles. Heavy rain occurred in the northern half of the country on the 11th and appreciable rain in the south on the 12th (2·25 in. at Borrowdale and at Glen Etive on the 11th). Widespread strong winds and gales were recorded on the 12th. In the rear of the main depression a spell of north-westerly winds prevailed, accompanied by wintry showers, local thunderstorms and long sunny periods. On the 15th and 16th another deep depression south of Iceland moved east-south-east to southern Norway; further precipitation occurred, chiefly in northern districts, and there were gales in the northern half of the country. Subsequently an anticyclone off our west coasts moved across England to Germany, while a trough moved east across Scotland. Precipitation occurred in north-west and north Scotland on the 17th but mainly fair sunny weather prevailed elsewhere. By the 19th a belt of high pressure extended from Greenland across the British Isles, and, on the 20th, a separate high over the Faeroes moved south-south-east to the North Sea where it remained almost stationary until the 23rd. The period from the 19th to the 23rd inclusive was generally dry and sunny on the whole. Temperature rose considerably in most places on the 23rd and the only really warm spell of the month was experienced from about the 23rd to the 25th (day temperature reached 70°F. or above at many places in England on the 24th and 25th and touched 78°F. at Wilmington, Kent, on the 24th and 79°F. at Camden Square, London, on the 25th). During the 25th a small depression south of Iceland moved east, and in its rear a cold northerly air stream covered the British Isles causing a rapid fall of temperature on the 26th. In the following days an anticyclone centred south of Iceland moved slowly south and became almost stationary westward of the British Isles, while pressure was relatively low eastward of the country. Cold weather prevailed, with wintry showers and long sunny periods, though it was rather dull locally including parts of east and south-east England. In the closing days of the month a shallow depression over the North Sea moved slowly south-west and turned west along the English Channel giving rain, sleet or snow in eastern districts on the 29th and in southern England on the 30th. Thunderstorms were experienced locally in the southern half of England on the 29th and 30th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	79	23	−1·4	135	+1	125
Scotland	64	18	−2·4	150	+3	114
Northern Ireland ...	64	27	−1·6	71	−1	111

RAINFALL OF APRIL 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·58	168	*Glam.*	Cardiff, Penylan ...	3·52	141
Kent	Folkestone, Cherry Gdn.	2·02	122	*Pemb.*	Tenby	2·74	119
,,	Edenbridge, Falconhurst	2·45	131	*Card.*	Aberystwyth	2·77	135
Sussex	Compton, Compton Ho.	3·59	180	*Radnor*	Tyrmynydd	5·91	160
,,	Worthing, Beach Ho. Pk.	2·39	153	*Mont.*	Lake Vyrnwy	5·42	171
Hants.	Ventnor Cemetery ...	2·43	142	*Mer.*	Blaenau Festiniog ...	7·78	125
,,	Bournemouth	3·10	173	*Carn.*	Llandudno	1·43	85
,,	Sherborne St. John ...	3·66	207	*Angl.*	Llanerchymedd ...	1·91	86
Herts.	Royston, Therfield Rec.	2·72	173	*I. Man*	Douglas, Borough Cem.	1·50	61
Bucks.	Slough, Upton	2·85	199	*Wigtown*	Port William, Monreith	1·23	56
Oxford	Oxford, Radcliffe ...	2·55	159	*Dumf.*	Dumfries, Crichton R.I.	2·34	99
N'hants.	Wellingboro' Swanspool	2·59	174	,,	Eskdalemuir Obsy. ...	5·40	159
Essex	Shoeburyness	2·06	170	*Roxb.*	Kelso, Floors	2·50	159
,,	Dovercourt	2·26	181	*Peebles*	Stobo Castle	3·76	180
Suffolk	Lowestoft Sec. School ...	3·81	257	*Berwick*	Marchmont House ...	2·77	137
,,	Bury St. Ed., Westley H.	4·12	269	*E. Loth.*	North Berwick Res. ...	2·37	169
Norfolk	Sandringham Ho. Gdns.	3·33	219	*Midl'n.*	Edinburgh, Blackf'd. H.	2·58	175
Wilts.	Aldbourne	3·51	190	*Lanark*	Hamilton W. W., T'nhill	2·82	151
Dorset	Creech Grange... ...	2·89	134	*Ayr*	Colmonell, Knockdolian	2·11	83
,,	Beaminster, East St. ...	2·36	100	,,	Glen Afton, Ayr San. ...	4·26	142
Devon	Teignmouth, Den Gdns.	1·78	89	*Bute*	Rothesay, Ardencraig ...	3·07	103
,,	Cullompton	2·27	100	*Argyll*	Morvern (Drimnin) ...	4·65	127
,,	Ilfracombe	4·14	198	,,	Poltalloch	2·94	97
,,	Okehampton Uplands	4·78	150	,,	Inveraray Castle ...	7·82	170
Cornwall	Bude, School House ...	2·45	130	,,	Islay, Eallabus	3·11	108
,,	Penzance, Morrab Gdns.	2·62	108	,,	Tiree	2·78	113
,,	St. Austell	3·99	141	*Kinross*	Loch Leven Sluice ...	2·43	127
,,	Scilly, Tresco Abbey ...	1·65	84	*Fife*	Leuchars Airfield ...	1·93	121
Glos.	Cirencester	3·02	162	*Perth*	Loch Dhu	6·00	127
Salop.	Church Stretton ...	2·41	111	,,	Crieff, Strathearn Hyd.	2·93	134
,,	Shrewsbury	1·84	124	,,	Pitlochry, Fincastle ...	2·54	114
Worcs.	Malvern, Free Library	2·88	160	*Angus*	Montrose, Sunnyside ...	2·15	118
Warwick	Birmingham, Edgbaston	2·95	170	*Aberd.*	Braemar	3·90	165
Leics.	Thornton Reservoir ...	2·31	136	,,	Dyce, Craibstone ...	2·66	129
Lincs.	Boston, Skirbeck ...	2·36	175	,,	Fyvie Castle	4·17	195
,,	Skegness, Marine Gdns.	2·66	199	*Moray*	Gordon Castle	2·87	164
Notts.	Mansfield, Carr Bank ...	1·34	77	*Nairn*	Nairn, Achareidh ...	3·40	243
Derby	Buxton, Terrace Slopes	3·69	126	*Inverness*	Loch Ness, Garthbeg ...	6·33	278
Ches.	Bidston Observatory ...	1·00	61	,,	Glenquoich	8·06	124
Lancs.	Manchester, Whit. Park	2·17	113	,,	Fort William, Teviot ...	6·88	153
,,	Stonyhurst College ...	2·62	97	,,	Skye, Duntuilm ...	4·56	140
,,	Squires Gate	1·45	81	*R. & C.*	Tain, Tarlogie House ...	4·30	235
Yorks.	Wakefield, Clarence Pk.	·89	53	,,	Inverbroom, Glackour...	7·20	194
,,	Hull, Pearson Park ...	1·07	69	,,	Applecross Gardens ...	5·36	157
,,	Felixkirk, Mt. St. John...	1·31	79	,,	Achnashellach	7·96	149
,,	York Museum	·87	54	,,	Stornoway Airfield ...	4·28	149
,,	Scarborough	1·46	94	*Suth.*	Loch More, Achfary ...	10·16	210
,,	Middlesbrough... ...	1·60	117	*Caith.*	Wick Airfield	2·45	123
,,	Baldersdale, Hury Res.	2·91	120	*Shetland*	Lerwick Observatory ...	4·40	192
Norl'd.	Newcastle, Leazes Pk....	1·45	91	*Ferm.*	Crom Castle	2·20	86
,,	Bellingham, High Green	2·72	126	*Armagh*	Armagh Observatory ...	1·72	82
,,	Lilburn Tower Gdns. ...	2·35	119	*Down*	Seaforde	1·73	66
Cumb.	Geltsdale	2·09	98	*Antrim*	Aldergrove Airfield ...	1·22	58
,,	Keswick, High Hill ...	4·84	158	,,	Ballymena, Harryville...	1·56	59
,,	Ravenglass, The Grove	1·16	47	*L'derry*	Garvagh, Moneydig ...	1·63	67
Mon.	Abergavenny, Larchfield	2·51	99	,,	Londonderry, Creggan	2·67	104
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Frontispiece]

V. Bjerknes

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VILHELM F. K. BJERKNES, For. Mem. R. S.

We deeply regret to have to record the death of Professor V. F. K. Bjerknes, which occurred at Oslo on April 9, 1951. He was 89 years old.

His name will live in meteorological history for his circulation theorems, his introduction into meteorology of the use of the absolute units of pressure, of geopotential and of charts of the topography of isobaric surfaces, and for his work on the theory of the oscillations of rotating fluids.

Three generations of the Bjerknes family have become internationally famous for research into the dynamics of fluids as C. A. Bjerknes, the father of V. Bjerknes was an eminent research worker in the theory of the hydrodynamics of " perfect " fluids, while the name of J. Bjerknes, one of the three sons of V. Bjerknes, is known to all meteorologists.

V. Bjerknes was born at Oslo on March 14, 1862, and educated at Oslo University where his father was Professor of Mathematics. While still a student he assisted in his father's researches and published his first paper, " New investigations in hydrodynamics "[1], at the age of 20 in 1882. He studied under Hertz from 1890 to 1891, and for several years afterwards his attention was mainly devoted to electrodynamics. Throughout his life he sought for analogies between hydrodynamics and electrodynamics.

In 1893, the year of his marriage to S. H. Bonnevie, he was appointed Professor of Mechanics and Mathematical Physics at the University of Stockholm, and while there he made, in 1898, his first major contribution to physical hydrodynamics in the theorem[2] for the rate of change of circulation in a baroclinic fluid. The mathematical formula was first published in 1896 in Poland by Silberstein but it was independently discovered by Bjerknes. Silberstein gave no physical applications of the theorem but Bjerknes saw its physical importance and gave numerous instances, such as the theory of sea breezes, of its applications in meteorology and oceanography[3]. His next major theorem was the formula[4] for the circulation in circuits on the rotating earth, published in 1901, with such applications as " A horizontal curve which contracts acquires cyclonic, one which expands, anticyclonic curvature." Between 1901 and 1907 Bjerknes worked in collaboration with J. W. Sandström on the application of these hydrodynamical theorems to meteorology, and conceived a plan for weather forecasting by graphical integration of the equations of motion which he described in the first article[5] of the 1904 volume of the *Meteorologische Zeitschrift*, " The problem of weather forecasting from the standpoint of mathematics and physics". An essential part of the scheme was the representation (diagnosis) of the existing state of the atmosphere in a convenient graphical form, and it was in a paper, " Aids to the calculation of the pressure distribution of the atmosphere during the international days of 1900 to 1903"[6], on this subject, that Bjerknes and Sandström introduced the absolute unit of pressure and employed geopotential as a measure of elevation. Following a visit to the United States in 1905 Bjerknes became a Research Associate of the Carnegie Institution which thereafter assisted him financially in his researches.

In 1907 Bjerknes was appointed Professor of Mechanics and Theoretical Physics at Oslo University. While at Oslo, he, in collaboration with Sandström, Hesselberg and Devik, produced his "Dynamic meteorology and hydrography"[7] published in two volumes, Part I: Statics and Part II: Kinematics, by the Carnegie Institution in 1910 and 1911 and devoted to calculations and graphical methods for the establishment of a satisfactory diagnosis of the state of the atmosphere. In this work the use of the topography of isobaric surfaces was proposed for the first time, and the relation, independent of air density, between the gradient of geopotential on such a surface and the geostrophic wind was pointed out. During this period, too, he played a prominent part[8] in the international acceptance of the millibar and the strong controversies associated with that subject.

Bjerknes paid his first visit to the British Isles in 1910. He came primarily to discuss with Sir Napier Shaw his methods and the making of observations suitable for accurate dynamical analysis. He delivered a lecture[9] (May 27, 1910) at University College, London, on the synoptic representation of atmospheric motions which was mainly concerned with the construction of charts of wind flow in the upper air and their use in the computation of the vertical currents.

The University of Leipzig decided in 1912 to establish a Geophysical Institute which V. Bjerknes was invited to direct as Professor of Geophysics. In his inaugural lecture[10], January 1913, he expressed his intention of directing all the energies of the new Institute to the calculation of the future state of the weather. Elsewhere, he has stated that on this basis he refused to take charge of the seismological work of the University. Stimulated at this time by a study of Helmholtz's paper of 1888 on " Atmospheric motions", and by von Ficker's papers on the spreading out of cold air over Siberia, Bjerknes was led to consider whether cyclones might originate as waves, and began the study[11] of wave motion in rotating compressible fluids.

Conditions at Leipzig became more and more difficult as the German students were mobilized for war service, so that in 1917 Bjerknes accepted an invitation to direct the Bergen Geophysical Institute to which he took his Norwegian " Carnegie Assistants " J. Bjerknes and H. Solberg who were joined later by T. Bergeron.

The study of lines of convergence and their association with changes of temperature had been commenced by Pezold, a German student at Leipzig, who was killed in the war. This work was taken over by J. Bjerknes and H. Solberg, and, with the aid of the observations from the dense network of observing stations set up in Norway during the war in an effort to mitigate the loss of foreign reports, led to the universally known doctrines of air masses and fronts.

In 1920 V. Bjerknes and Helland Hansen invited Sir Napier Shaw and three other British meteorologists (L. F. Richardson, A. H. R. Goldie and C. K. M. Douglas) to visit the Bergen Geophysical Institute to take part in a series of meetings on dynamical meteorology at which the new Bergen theory was discussed. The enthusiasm of the Bergen research school, the kindness and hospitality of its members greatly impressed the visitors.

V. Bjerknes's part in the Bergen work lay largely in the theoretical interpretation, contained in his large works[12] on the dynamics of the circular vortex and in shorter papers[13] on the linearized hydrodynamical equations of small disturbances, of the empirical discoveries of his young collaborators. The team divided in 1926 when V. Bjerknes returned to his old chair at Oslo taking with him the mathematician Solberg. He retired from this post in 1932.

The work of his whole career was summed up in the great work, " Physical hydrodynamics with applications to dynamical meteorology "[14] written by V. and J. Bjerknes, H. Solberg and T. Bergeron and published in 1933.

V. Bjerknes made numerous visits to this country after 1919. In 1919 he lectured to the Royal Meteorological Society on " The structure of the atmosphere when rain is falling[15], and in 1924 to the Royal Institution on "The forces which lift aeroplanes"[16] and to the Royal Meteorological Society on " Polar-front meteorology"[17]. In 1927 he visited Edinburgh and St. Andrews in company with Nansen, Helland Hansen and Sverdrup when that gallant band renewed many old acquaintanceships.

In 1936 he presided over the Edinburgh meetings of the International Association of Meteorology to which he read a paper[18] on the application of his circulation theorems to the general circulation of the atmosphere and its oscillations. And in 1946 on the occasion of the deferred Newton Tercentenary Celebrations he was a delegate with Størmer to the Royal Society.

Outside his purely meteorological papers may be mentioned one on " Solar hydrodynamics "[19] inspired by his discussions with the astronomers of the Mount Wilson Observatory in 1924. This is a " hydrodynamical discussion of internal solar motions, especially vortex motions, for explaining sunspots and their properties"—a paper which has also much interest for the meteorologist.

To mention V. Bjerknes's British honours only, he was a Foreign Member of the Royal Society (1933) and of the Royal Society of Edinburgh (1930), Honorary Member of the Royal Meteorological Society (1913), Symons Medallist (1932), and LL.D. Hon., St. Andrews (1926).

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DISTRIBUTION OF RAINFALL ROUND A HOUSE

By R. E. LACY, B.Sc.

Summary.—Measurements have been made of the rain collected in a number of rain-gauges set up round a house. The results of the first eight months' observations are presented. Over this period an area round the house equal in area to the house itself received less than the normal amount of rain. The results are also used to demonstrate the effect of shelter on the catch of rain-gauges.

Introduction.—In connexion with work on house foundations it was required to determine what quantity of rain fell close to the house, and how this quantity varied with distance from the walls. Accordingly, in the autumn of 1948 a number of rain-gauges were set up as indicated in Fig. 1, at various points round a house at the Building Research Station. The exposure of the house is not as good as could be desired, as there are buildings fairly close in all directions from north-west to east, but since most rain falls with winds from the south to west their effect on the results was probably small. No house with a clearer exposure was available. Fig. 2 (facing p. 212) is a photograph of the house taken from the north. The present note sets out and comments on the results obtained during the first eight months of the experiment.

Experimental method.—The rain-gauges used were Meteorological Office Mark II 5-in. diameter rain-gauges, with the lips of the collecting funnels set at the standard height of 12 in. above ground level.

Gauges 3, 4, 7 and 8 were placed as close as possible to the walls, with the other gauges at various distances from the west, north and east walls. It was not possible to put a second gauge at a suitable distance from the south wall. Gauge 1 was placed 18 ft. from the north wall, a distance equal to the height of the house eaves above ground level. The house has a tiled roof pitched at 40°, with a gutter projecting 12 in. beyond each wall.

The gauges were read, not at fixed intervals, but at the conclusion of periods of rain falling with one direction of wind, as far as this was possible, so that the variation in the pattern of the rainfall with wind speed and direction could

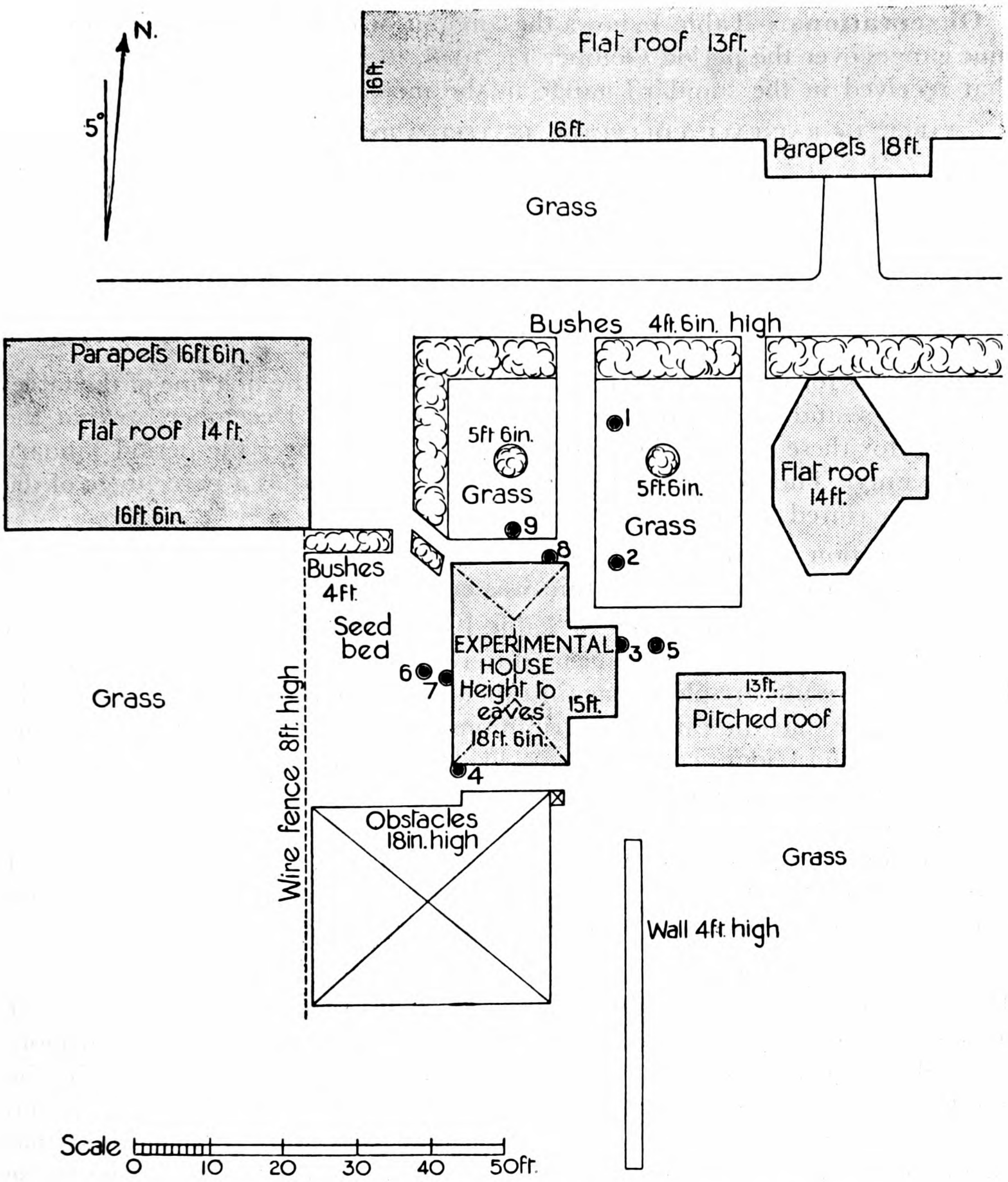
N.
5°
Flat roof 13ft.
16ft.
16ft.
Parapets 18ft.
Grass
Bushes 4ft.6in. high
Parapets 16ft 6in.
Flat roof 14ft.
16ft. 6in.
5ft 6in.
Grass
1
5ft.6in.
Grass
2
9
8
Flat roof 14ft.
Bushes 4ft.
Seed bed
EXPERIMENTAL HOUSE Height to eaves 18ft. 6in.
15ft.
3
5
6
7
4
13ft.
Pitched roof
Grass
Wire fence 8ft. high
Obstacles 18in. high
Grass
Wall 4ft. high
Scale
0
10
20
30
40
50ft.

FIG. 1—POSITION AND EXPOSURE OF THE RAIN-GAUGES

be obtained. The periods of rainfall discussed below do not therefore coincide with particular rain days, but may in some cases comprise a rainfall over part of a day, or in other cases may cover several days' rain.

The times at which rain fell were determined from a Meteorological Office tilting-siphon rain recorder situated in the meteorological enclosure some 200 yd. from the house, where the standard 5-in. gauge was also placed. The wind speed during the rain was determined from a wind-run recorder driven by a cup contact anemometer mounted on a 10-ft. high mast, which was set up on a flat roof 16 ft. above ground level. It was not possible to install an anemometer in a better position near the house. Wind direction was obtained from the records of a directional wind recorder at Abbotts Langley, one mile away.

Observations.—Table I shows the amount of rain received in each of the nine gauges over the period October 11, 1948, to May 31, 1949, together with that received in the standard gauge in the meteorological enclosure.

TABLE I—RAINFALL COLLECTED IN TEST AND STANDARD RAIN-GAUGES

	TEST GAUGES									
	1	2	3	4	5	6	7	8	9	Standard
					millimetres					
October to May	331·9	320·0	75·4	...	...	338·1	259·6	...	282·7	337·2
January to May	...	...	...	124·3	147·9	...	...	51·7	...	167·8
					per cent.					
	98·4	94·9	22·4	74·1	88·2	100·3	77·0	30·9	83·8	100

The results for the whole of the period are shown on the first line of the table. Gauges 4, 5 and 8 were only installed at the end of December, so that the readings for these gauges, shown on the second line, cover the period January to May only. The third line shows the results expressed as a percentage of the rainfall measured in the standard gauge.

The duration of rainfall over the whole period was 243 hr. and the mean wind speed during the time the rain was falling was 6·0 m.p.h.

The percentage figures given in Table I have been plotted in Fig. 3, which is a replica of one of the diagrams used to record the results of this experiment. In Fig. 4 the results are plotted against the distance of the gauges from the wall, and it is clear that the rainfall distributions on the east and north sides of the house are almost identical. It seems likely, from the value of 74 per cent. obtained for gauge 4, that the distribution on the south side is similar to that on the west, and two curves have therefore been drawn through the points, one covering the north and east points, the other covering the south and west points. From the curves it is estimated that the distances within which less than the normal amount of rainfall was received were:

north and east 8 ft. south and west 3 ft.

These figures apply to the middle of the walls, away from the corners. Near the corners the sheltering effect of the house will not be so great, so that more rain will be received on the ground near the house than at points opposite the middle of the wall. With the help of the curves of Fig. 4, the 50 per cent. and 100 per cent. isopleths have been drawn in Fig. 3. It appears from these that during the period under consideration an area of ground round the house approximately equal to the area of the house itself received less than the normal amount of rain. Nearly 10 per cent. of this area received less than half the normal amount.

Effect of shelter on rain-gauges.—The results have been used in the preceding section to estimate the amount of shelter given by the house to the surrounding ground. Table II sets out the percentage readings for the nine gauges by months, together with wind speed, duration of rainfall, and rainfall in the standard gauge.

It will be seen that apart from gauge 9, 4 ft. from the north wall, only the inner gauges, 3, 4, 7 and 8, set under the eaves of the house, show very marked differences from the readings of the standard gauge. This is also shown by Table III, which gives the mean value for each of the test gauges, together with the corresponding standard deviation of the monthly totals, which is a measure of the variability of the observations from month to month.

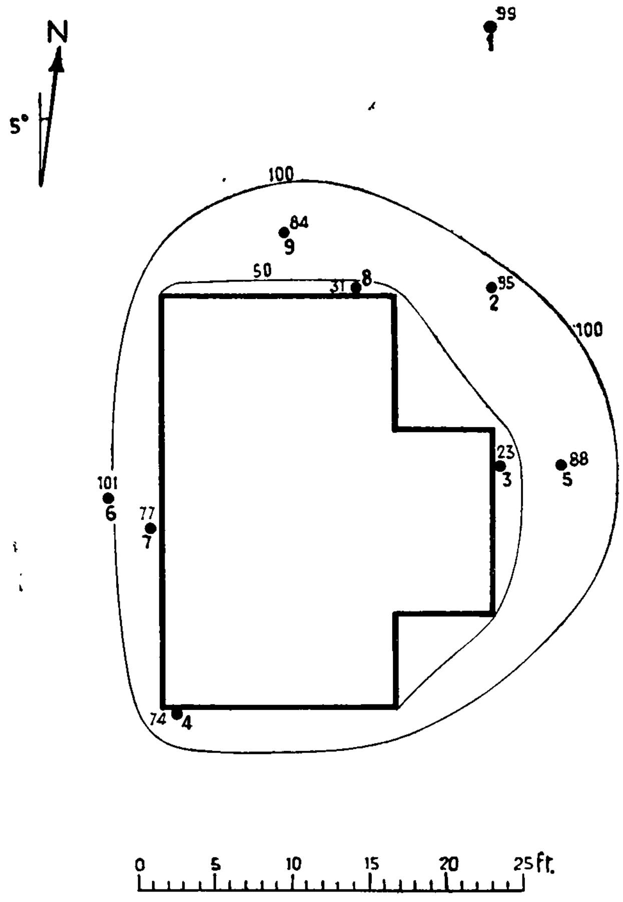
N
5°
99
100
84
9
50
31
8
95
2
100
23
3
88
5
101
6
77
7
74
4
0
5
10
15
20
25ft.

FIG. 3—RAINFALL MEASUREMENTS ROUND EXPERIMENTAL HOUSE, EXPRESSED AS A PERCENTAGE OF STANDARD

Rainfall (standard gauge), 13·28 **in.** Period, Oct. 11, 1948–May 31, 1949.
Duration of rainfall, 243 hr. Mean wind speed, 6·0 m.p.h.

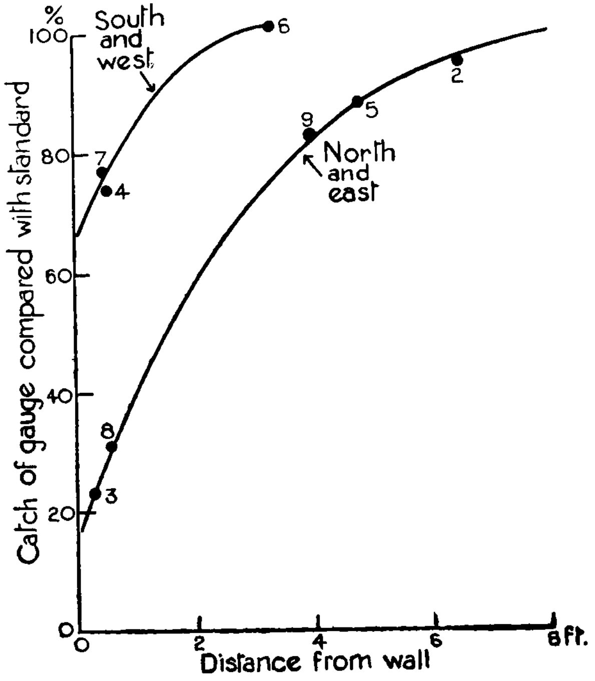

FIG. 4—VARIATION OF RAINFALL WITH DISTANCE FROM WALL

TABLE II—MONTHLY READINGS OF RAIN-GAUGES

Period	Duration	Wind speed	TEST GAUGES									Standard
			1	2	3	4	5	6	7	8	9	
1948–49	hr.	m.p.h.	*percentage of standard*									mm.
Oct. 11–31	27·2	4·0	101	97	16	—	—	105	94	—	92	50·0
Nov. 1–30	35·4	5·4	100	100	43	—	—	95	55	—	95	46·8
Dec. 1–Jan. 2	49·2	7·5	96	85	12	—	—	101	89	—	67	72·6
Jan. 3–31	22·8	4·7	101	98	43	87	81	98	54	28	84	21·4
Feb. 1–26	23·6	7·2	100	96	36	99	85	94	80	23	68	34·9
Feb. 27–Mar. 21	22·5	4·4	100	101	25	90	96	102	69	27	92	31·8
Mar. 22–Apr. 30	31·7	8·5	95	96	11	53	82	103	93	56	90	37·8
May 1–31	30·4	4·5	96	96	15	54	94	102	62	19	93	41·9

TABLE III—MEAN MONTHLY PERCENTAGES AND STANDARD DEVIATIONS OF MONTHLY PERCENTAGES OF TEST RAIN-GAUGES

Gauge	1	2	3	4	5	6	7	8	9
Mean percentage	98·6	96·1	25·1	76·6	87·6	100·0	74·5	30·6	85·1
Standard deviation of percentages	2·5	4·9	13·7	21·5	7·0	3·9	16·7	14·6	11·3

It would appear that if monthly readings only are considered, gauge 1, 18 ft. from the house (giving a shelter ratio of approximately 1:1) and on the side which is sheltered from the prevailing winds, gives a measure which may well be acceptable as a measure of the true rainfall. This somewhat unexpected result is probably to be explained by the fact that the experimental site is to some extent sheltered by a belt of trees about 200 yd. to the south, as a result of which the mean wind speed in the neighbourhood of the house is never very high, being little more than half that at a well exposed site about a mile to the west. It was shown by Hudleston at Hutton John[1,2], in a district freely exposed to wind, that a rain-gauge with a shelter as severe as that of gauge 1 will catch only 60 per cent. or less of the true rainfall in a strong wind.

Gauge 6, only 3 ft. from the west wall of the house, has a mean monthly catch of 100·0 per cent., with a standard deviation of 3·9 per cent. It is exposed to the majority of the rain-bearing winds, and will also catch a little rain with an easterly wind, if the wind strength is not too great. Even this gauge may therefore be expected to give fairly reliable monthly totals of rainfall if there is the normal proportion of W. and E. winds.

However the variability of short-period totals is much greater: 38 sets of readings were obtained during the period under consideration, some of these, as indicated above, comprising falls over more than one day, and for these, again expressed as percentages of the catch in the standard gauge, the mean for gauge 1 is 96·8 per cent., with a standard deviation of 7·2 per cent.

During the period October 11 to December 18, 1948, when 13 separate sets of readings were obtained, a gauge, A, was situated 36 ft. south of the house, and, there being no other near-by obstructions, could be considered to have a "normal" exposure as recommended in the "Meteorological observer's handbook". Considering the readings of gauges A, 1 and 6 for this period we have:—

Gauge No.	A	1	6
		per cent.	
Mean of 13 observations	103·6	99·8	95·0
Standard deviation ...	3·8	4·8	29·2

The correlation between the standard and gauge A is good, although over this period A tended to read higher than the standard. Gauge 6, which gave monthly readings closely agreeing with those of the standard, shows up badly when individual readings are considered, due to the considerable shelter given by the house from rain falling with easterly winds. The standard deviation of the readings of gauge 1 is only a little greater than that of readings of gauge A, from which it is concluded that some of the variation is due to real differences between the rainfall at the site of gauge 1 and that at the meteorological enclosure, only part of the variation being due to the effects of shelter.

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VARIABILITY OF PERCENTAGE ANNUAL RAINFALL OVER SHORT DISTANCES IN SCOTLAND

By R. A. WATSON, B.A.

Two rain-gauges situated a few miles apart are often used as a check on each other's readings, but so far as is known no numerical measure of the difference has actually been observed between pairs of such gauges. Measures of this sort are necessary in attempting to assess the accuracy of the estimated rainfall over a catchment area from the readings of a number of gauges over the catchment.

If R_x and R_y are the mean annual rainfalls at two neighbouring places X and Y, and $x_1, x_2, x_3 \ldots\ldots, y_1, y_2, y_3 \ldots\ldots$ are the departures of the observed rainfall in successive years expressed as a percentage of R_x and R_y it is reasonable to assume, and actual test verifies, that $\Sigma x_1^2 = \Sigma y_1^2$ and therefore

$$\frac{\Sigma (x_1 - y_1)^2}{\Sigma x_1^2} = 2(1 - \rho)$$

where ρ is the correlation coefficient between the annual rainfall at X and the annual rainfall at Y both expressed as a percentage of the mean or

$$\frac{\text{Standard deviation of the percentage difference}}{\text{Standard deviation of the rainfall}} = \sqrt{\{2(1-\rho)\}}$$

This means that the ratio is only reduced to 0·5 even if the correlation coefficient is 0·875.

In *British Rainfall 1925* Glasspoole worked out the correlation of annual rainfall at a large number of places with Glenquoich and with Oxford. His maps cannot be used to determine the correlation between places only a few miles apart, but it is interesting to note that only a very small area of Scotland is shown as having a correlation with Glenquoich greater than 0·8. On the other hand half the area of England and Wales is enclosed within the 0·8 correlation line with Oxford.

Except near the large towns there exist few pairs of gauges which have been in operation for a sufficiently long time without some change, but figures for the pairs in Table I were worked out for the 25-year period 1926–50. Even in these selected places there are known to be some breaks in the continuity of the record but it is hoped that these are not important.

TABLE I—COMPARISON OF NEIGHBOURING RAIN-GAUGES IN SCOTLAND

County or district	Position of gauges	Distance apart	Standard deviation	Standard deviation of difference	Correlation coefficient
		miles	%	%	
Edinburgh	Royal Botanic Garden Royal Observatory	3	13·8	3·8	0·96
Wigtown	Port William (Monreith) Garlieston (Galloway House)	7	14·2	5·5	0·93
Argyll	Strachur Park Inveraray (Castle Gardens)	5	18·0	8·0	0·90
Aberdeen	Aberdeen (Mannofield) Dyce (Craibstone)	5	10·0	5·1	0·87
Loch Linnhe	Ardgour House Onich	3	19·3	7·5	0·93
Argyll	Islay (Eallabus) Islay (Rhuvaal)	11	12·3	6·3	0·89
Renfrew	Loch Thom Inverkip	3	15·0	7·6	0·87
Shetland	Lerwick Observatory Bixter	16	11·5	5·8	0·87
Hebrides	Tiree	...	14·4	...	...

There was no significant difference between the standard deviations of rainfall at the two places compared. It is not safe from so few pairs to attempt any generalization as to the geographical distribution of the standard deviation of the differences. The big values may well be associated with larger rainfall or with sharper relief of the land, but except for the very small value for the two Edinburgh stations the most striking fact is that the figures are so nearly grouped round a mean of about 7 per cent. This means that, if we express the year's rainfall of two closely neighbouring places as a percentage of the long-period average, we must expect differences of over 7 per cent. in about one out of three cases and even differences of 14 per cent. in one out of twenty cases without, from this fact alone, raising suspicion of the correctness of the observations. The ordinary practice of comparison always takes into account factors other than the mere differences from neighbouring records.

In the article in *British Rainfall* already mentioned, Glasspoole worked out the standard deviations of annual rainfall at a number of places in the British Isles for the period 1881–1915. The differences between Glasspoole's values for the earlier period and those now worked out are not large, but, such as they are, suggest that the annual rainfall was somewhat less variable than in the standard 35-year period than in the one now considered especially in the west of Scotland. To test this the standard deviation for Tiree was worked out and is recorded in Table I. Unfortunately, there was a change of site of the rain-gauge on Tiree in 1942. Any lack of continuity in the records is liable to increase the standard deviation. Although the increase at Tiree from this cause is probably small it cannot be evaluated with any certainty as yet owing to the isolated position of the record.

HONOURS AND AWARDS

Charles Chree Medal and Prize

Sir George Simpson, F.R.S., has been awarded the Charles Chree Medal and Prize of the Physical Society for distinguished work in terrestrial magnetism and atmospheric electricity.

METEOROLOGICAL RESEARCH COMMITTEE

The Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee held meetings (14th and 15th respectively) on May 10 and 23, 1951. Dr. A. W. Brewer (Clarendon Laboratory, Oxford) has recently become a member of this Sub-Committee.

At the first of these meetings the main discussion was concerned with investigations which might help to improve the forecasting of fog. In this connexion Mr. J. M. Craddock presented a paper[1] on forecasting radiation fog. Papers on the structure of the tropopause surface[2] and the distribution of high and medium cloud near the jet stream[3], the former by Mr. J. S. Sawyer and the latter by Mr. J. S. Sawyer and Miss B. Ilett, were also discussed.

At the second meeting there was a long discussion of the validity and value of the various approximations made in the Rossby, Charney and Sutcliffe approaches to the short-term dynamics of the atmosphere. Mr. H. H. Lamb's report[4] on an attempt to classify the circulation patterns of the northern hemisphere was also discussed and invoked considerable interest; it appears that a workable classification is not possible for the hemisphere. Other papers discussed were by Mr. A. H. Gordon[5] on seasonal changes in the mean pressure distribution over the world (largely based on observations from ships), and by Mr. F. H. Bushby[6] giving a second report on tests of the Charney-Eliassen method of computing forecast 500-mb. contour charts; the latter paper deduces that forecasts by conventional methods are more accurate than the computed.

The sixteenth meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on May 17.

An interesting paper[7] by Mr. N. E. Rider on the relation between aerodynamic drag and wind profile over grassland was considered.

A paper by Dr. Brewer and Mr. Palmer on the freezing of supercooled water was also discussed. The results of this work refute the claim of Rau that pure water can be supercooled to −72°C. by repeated freezing and melting.

The Committee considered a report on the frequency of jet streams over the British Isles and also a short note on some statistics of rate of rainfall in southern England.

[1] *Met. Res. Pap., London,* No. 624, 1951.
[2] *Met. Res. Pap., London,* No. 612, 1951.
[3] *Met. Res. Pap., London,* No. 633, 1951.
[4] *Met. Res. Pap., London,* No. 632, 1951.
[5] *Met. Res. Pap., London,* No. 646, 1951.
[6] *Met. Res. Pap., London,* No. 622, 1951.
[7] *Met. Res. Pap., London,* No. 626, 1951.

ROYAL METEOROLOGICAL SOCIETY

Physics of natural rain formation

The Annual General Meeting of the Society was held in the Society's rooms, 49 Cromwell Road, on Wednesday April 18, 1951, with the President, Sir Robert Watson-Watt, in the Chair. After the adoption of the report of the Council for the year 1950, the President presented the Symons Gold Medal to Sir Geoffrey Taylor, M.A., F.R.S., Yarrow Research Professor of the Royal Society, in recognition of his classical work in atmospheric turbulence and related subjects in meteorology.

There then followed an ordinary meeting at which Dr. E. G. Bowen, Director, Radio Physics Division, Commonwealth Scientific and Industrial Research Organization, Australia, gave a lecture on recent work by his division into the physics of cloud and rain.

Dr. Bowen said that his division's work could be divided into three distinct parts: cloud physics, the physics of natural rain formation, and studies of artificial rain formation. He confined his lecture to the second of these subjects.

In the main observations had been made with 10-cm. radar sets which can detect raindrops, snow-flakes or ice particles provided they are big enough, the intensity of echo being proportional to $\Sigma ND^6/\lambda^4$ where N is the number of raindrops of mean diameter D and λ the radar wave-length. These observations could be taken either on the ground or in the air, and were so arranged as to give vertical cross-sections through regions of rain. Dr. Bowen showed 4 slides of radar observations, taken from an aircraft, of rain falling from a cloud, no part of which at any time reached the freezing level. The rain was falling into " wild " country near Sydney, and it was therefore not possible to quote actual intensities of the rainfall but the echo was very similar to that given by measuring rainfall intensity of 5 mm./hr.

This clear-cut contradiction of the Bergeron theory[1] of rain formation (that all appreciable rain is produced by the melting of ice crystals) required explanation, and Dr. Bowen described his coalescence theory of rain formation in which all cloud and rain droplets are assumed to coalesce on impact. With this assumption, and, accepting Langmuir's formula for the collection efficiency of a drop falling through a cloud of smaller droplets, the growth of drops has been calculated in differing cloud conditions of varying vertical air velocities. A typical result, with a vertical air velocity of 100 cm./sec. in a cloud of water content 1 gm./m.^{3} and average droplet size of 20μ, gave a drop growing in size more and more rapidly, its terminal velocity overcoming the up-draught at a height of 7,000 ft. above the cloud base, and eventually falling out of the cloud as a raindrop with diameter about 1·5 mm., the whole operation taking about an hour. Higher vertical air velocities gave larger raindrop sizes and drops reached greater heights; increase in water content increased the size of the raindrops only slightly but reduced the cloud thickness traversed; decreased collection efficiency decreased the raindrop size only slightly but required a greater increase in cloud thickness; and increase in average size of cloud droplet gave relatively small changes in both raindrop size and cloud thickness.

The number of raindrops per unit volume of cloud is given by $N=n/(v-u)$ where n is the number of drops crossing unit area, v is the upward air velocity and u the terminal velocity. This number, and therefore the rain-water content, must become very large near the top of the trajectory of a growing drop. This concentration of rain-water at a definite level had been confirmed by experience at a height half-way up the cloud.

Dr. Bowen showed slides of theoretical and observed variation with height of both raindrop density (N) and rain-water content, and the curves were of the same general form. He also showed radar photographs of rain coming from clouds whose tops were limited by an inversion below the freezing level, and drew attention to 200–300 mm. of rain per year occurring in Hawaii with a regular trade-wind inversion at 10,000–12,000 ft. (i.e. below the freezing level.)

Dr. Bowen went on to show radar photographs of rain falling from cloud which had been produced by the Bergeron process, and, in addition to the bright band visible near the freezing level (due to the melting of ice crystals), he showed the occasional existence of a further bright band formed some 8,000 ft. higher than the freezing level due, he thought, to a sudden freezing of supercooled drops at that level. In this connexion he gave an outline of recent work in the United States on the spontaneous freezing of supercooled drops.[3]

In conclusion, a film was shown of what occurs on a radar screen, but speeded up some 120–150 times. Both the freezing-level band and the upper band were seen. The upper band forms and almost immediately begins to fall towards the freezing-level band; when the bands meet the rain suddenly intensifies. The upper band then reforms at a higher level and repeats the process. Other sequences in the film showed shower echoes quite clearly below the freezing level, and one occasion with both Bergeron and coalescence processes acting together to produce rain.

In the brief discussion that followed the lecture some doubt was raised about the explanation given for the upper bands; Dr. Bowen agreed there were still considerable cracks in the theory. Mr. Ludlam stated that there had been no previous convincing evidence of rain falling from cloud below freezing level; he was now forced to admit that it did occur.

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2. RYDE, J. W.; The attenuation of radar echoes produced at centimetre wave-lengths by various meteorological phenomena. " Meteorological factors in radio-wave propagation ". London, 1946, p. 169.
3. HEVERLY, J. R.; Supercooling and crystallization. *Trans. Amer. geophys. Un., Washington D.C.,* 30, 1949, p. 205.

Presidential Address

Sir Robert Watson-Watt, F.R.S., delivered his Presidential Address on the subject " Meteorology and aviation " before the meeting of the Society held on May 16, 1951.

Sir Robert discussed the history of the AIRMET broadcasts in the first part of his address. He gave a summary of the development of these broadcasts and of their cancellation a year ago following the re-allocation of the frequency used for them at the Copenhagen International Broadcasting Conference of 1948. He emphasized that the AIRMET broadcasts, though arranged initially for the use of aviators, had come to be widely used by many other members of the community. He was strongly of the opinion that the five-minute B.B.C. broadcasts of Meteorological Office forecasts were no substitute for AIRMET with its intimate contact with the actual forecaster, and he urged the introduction of revised AIRMET broadcasts designed to serve all interests.

In the second part of his address, Sir Robert dealt with the provision made by the Government for the satisfaction of the meteorological requirements of the community. He gave an outline, based on the *Annual Reports,* of the incorporation of the Meteorological Office in the Air Ministry, and said he considered that a public review of the position of the Office as part of the Air Ministry was needed because the present organization tended to give undue priority to aviation requirements.

The improvement in meteorological knowledge from which the whole community benefited had been very largely produced by the demands of aviation, but more attention should now be paid to the needs of agriculture and other industries. The slogan " Meteorology in the service of production " should be the guide. He also urged the installation in Britain of automatic telephone weather information services such as are to be found in the United States and on the continent of Europe.

The President also suggested that the Society should set up interest groups, say for agriculture and horticulture, education, engineering, fisheries, and non-scheduled flying, domestic and social, for the discussion of the particular meteorological requirements of the interest in question.

Sir Robert said, in concluding, that the views he had expressed were entirely his own, and that he had not consulted the Director of the Meteorological Office or other Fellows of the Society in the preparation of his address.

PHYSICAL SOCIETY

At the annual general meeting of the Physical Society in the Royal Institution on Wednesday, May 2, Professor S. Chapman, F.R.S., gave his presidential address which had been postponed from last year because of his departure for the United States. The present President, Professor L. F. Bates, F.R.S., took the Chair. The title of the lecture was " Some phenomena of the upper atmosphere ".

After giving a brief history of the development of the study of the upper atmosphere from the early notions of a finite atmosphere with a continual temperature lapse with height, modified later by the work of Teisserenc de Bort and W. H. Dines and others to the notion of the isothermal stratosphere, Professor Chapman went on to discuss the modern ideas of temperature structure and the theory of the high temperatures of over 1,000°A. in the outer fringes of our atmosphere. The existence of a temperature maximum at 40 Km. was first detected by anomalous sound propagation while the temperature minimum at 80 Km., which at first seemed to clash with the theory of the maximum, was first worked out by Vegard from the band spectra of auroræ. These observations have been confirmed by observations on meteor trails.

The diurnal pressure variation had been shown by G. I. Taylor to be due to the solar tide in the atmosphere which, because of its natural period of nearly 12 hr., is amplified a hundred times by resonance. It can be shown that a natural period of 12 hr. requires a temperature minimum above 60 Km.

Attempts have been made to obtain samples of the air at high altitudes to test the theories of stratification, and samples taken by means of rockets from 60 Km. showed no change in the composition. It is expected that samples will soon be obtained from 100 Km. where, it is believed, dissociation of oxygen molecules takes place. Professor Chapman suggested that the names " turbosphere " and " homosphere " be given to the two regions of the atmosphere in which, in the first case, turbulent mixing takes place and, in the second, where no vertical mixing should occur. Mention was made of the various methods tried to obtain measurements of temperature and density from high levels. For temperature measurements these included the sound-ranging method which required elaborate ground organization, direct recording of the shock wave angle at the nose of a rocket, the release of grenades at fixed intervals from a rocket and, for the density, the observations of the scatter from a modulated searchlight beam, such as is being done now in Alaska, where measurements up to 60 Km. have been made in the very clear atmosphere there.

Although the existence of the temperature increase in the upper ionosphere is fairly certain and the presence of the temperature maximum due to absorption by ozone has been established, nevertheless, the radiative balance of the upper atmosphere has not yet been worked out. It was hoped that a new method of laying artificial " meteor trails " of sodium vapour from rockets, suggested by D. R. Bates, would provide useful data on winds at high levels.

Dealing with the light of the night sky, Professor Chapman mentioned that the oxygen, nitrogen and sodium lines were enhanced at twilight and that the continuance throughout the night of the sodium emission had not yet been explained; it must mean that the sodium atoms could draw on local energy by some means unknown. Another recent discovery was the infra-red emission by hydroxyl (OH). Doppler broadening of the H_β and H_γ lines in the auroral spectra observed by C. W. Gartlein and the displacement of the H_α line observed by A. B. Meinel in observations on auroræ in the direction of the magnetic zenith showed that particle velocities of 3,000 Km./sec. must be reached. The theory of the existence of the hydrogen lines, first proposed by Lord Cherwell, was that the particles left the sun as protons which, on reaching the earth's atmosphere, ionized and excited other atoms, then acquired electrons so becoming hydrogen atoms, which then produced the hydrogen line.

The effect of cosmic rays was mainly in the formation of new gases by nuclear reactions. Suspected evidence for the escape from the atmosphere of fast-moving particles was the phenomenon during disturbed conditions of the F layer rising and disappearing into space to be replaced after about one hour by a new F layer. Calculations can be made from daily magnetic variations of the electric currents in the ionosphere. By this means the form and intensity of the current flow but not its height can be obtained. Isopleths of current flow had been sketched and showed that on disturbed days the normal circulation pattern was replaced by an overall flow and by two intense circulations near the magnetic pole in which two zones of maximum convergence coincided with the regions of maximum occurrence of auroræ. From the analogy with the jet stream of meteorology, Professor Chapman suggested that the name for these zones of intense current flow should be the " electrojet ". From the observations of the Observatory of Huancayo there was evidence of another " electrojet " in the tropics covering from 2° to 3° of latitude, and the Magnetic Association now meeting in Brussels were arranging an expedition to make the necessary measurements to verify this theory.

LETTERS TO THE EDITOR

" John Constable's clouds "

In the review of " John Constable's clouds " in the February issue of the *Meteorological Magazine* it is stated that Howard's paper " On the modifications of clouds " appeared in 1820. It is not clear whether this date is quoted from the book under review but it is wrong, as the paper was first printed as early as 1803 in the *Philosophical Magazine*. It was later reprinted several times—in Rees's " Cyclopaedia ", Nicholson's *Philosophical Journal* (Vol. 30), the 2nd edition of Howard's " Climate of London ", etc. One edition, in 1865, was illustrated by lithographs, most of them taken from watercolours by Howard, but that was after his death. For Howard was " satisfied, both by reflection and experience, that the real student will acquire his knowledge in a more solid manner, by the observation of nature, without the aid of drawings, and that the more superficial are liable to be led into error by them."*

Plates were included in the 1803 publication, but are missing from my copy. Can anyone state whether Howard had reached the view expressed in the above quotation in time to have the plates removed from some issues?

F. E. DIXON

81 Ranelagh Road, Dublin, Ireland, April 25, 1951

[The author of "John Constable's Clouds " states (p. 7) that Howard's classification of clouds was first published in the *Philosophical Magazine* in 1803. His point is, however, that the painting by Constable of a group of cloud studies in 1821–22 was occasioned by the publication of the classification in 1820 in the first edition of Howard's " Climate of London ". In fact, Howard says he has found that the " copying of a particular form of each modification . . . . tends to limit too much the reader's views . . . . while the exhibition of many varieties will only serve to puzzle him." Plates are included in the copy of the 1803 paper in the Meteorological Office Library.—Ed. *M.M.*]

Duststorm at North Front, Gibraltar

Visibility over the western Mediterranean is occasionally limited by the widespread diffusion of dust, but, in the vicinity of Gibraltar, this normally produces only a slight haze. The main dust-producing areas are well to the south of Gibraltar, and the Atlas Mountains prove an effective barrier to any extensive northward movement of dust. Minor dust-producing areas are located in the French Moroccan coastal plain, particularly around Casablanca, Rabat and Port Lyautey, where there are extensive areas of very sandy soil. Duststorms developing in this area are usually quite local, and are rarely observed north of Port Lyautey.

However, at 1830 G.M.T. on December 5, 1950, for the first time on record, the visibility at Gibraltar was reduced to less than 1,000 yd. by dust and sand. The duststorm was associated with a strong south-south-westerly wind, averaging 30 kt. with gusts to 60 kt. for a short period, just before a pronounced cold front. A perceptible deposit of reddish brown dust was noted in many places throughout the Colony. The frontal rain commencing 25 min. later also contained a proportion of dust, and the effect of this was particularly noticeable on all metallic surfaces, which were quickly spattered with a reddish brown paste.

The synoptic charts for 1200 G.M.T. on December 5 showed a depression off Cape St. Vincent moving rapidly east-north-east. The associated cold front at this time was lying north-north-east to south-south-west about 100 miles west of the Moroccan coast, and at 1500 was approaching Casablanca. Surface winds freshened rapidly ahead of the cold front, and by early afternoon stations in French Morocco were reporting south-westerly winds of between 25 and 35 kt. Duststorms, reducing visibility to less than 500 yd., were reported at

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*HOWARD, L.; The climate of London. London, 2nd edn 1883, Vol. I, p. lii.

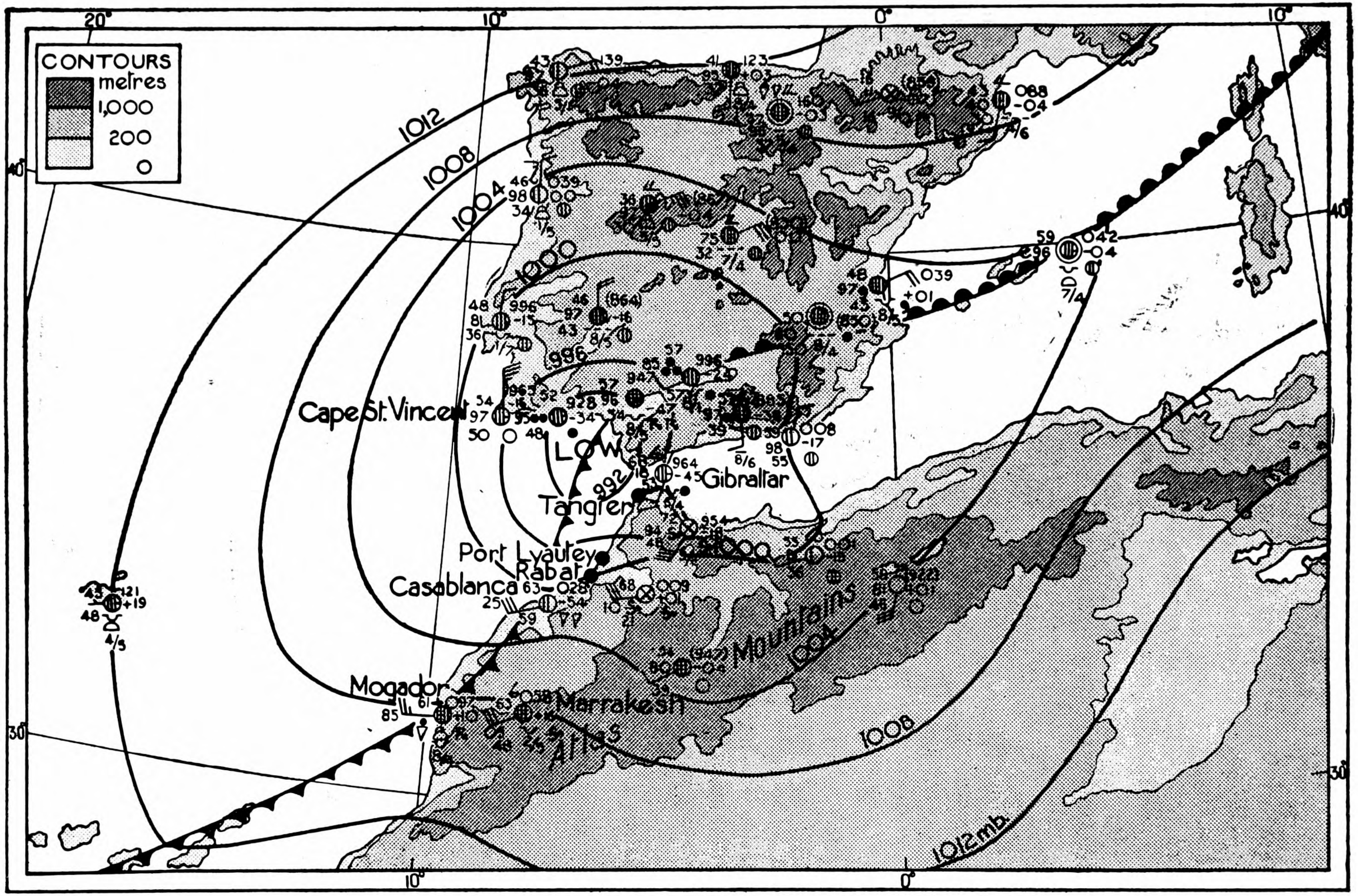
CONTOURS
metres
1,000
200
0
20°
10°
0°
10°
40°
30°
1012
1008
1004
1000
996
992
1012 mb.
LOW
Cape St. Vincent
Gibraltar
Tangier
Port Lyautey
Rabat
Casablanca
Mogador
Marrakesh
Atlas
Mountains

FIG. 1—SYNOPTIC CHART, 1800 G.M.T., DECEMBER 5, 1950

Port Lyautey at 1200 and at Casablanca and Rabat at 1500. The dust moved quickly north-eastwards up the coast and, during the late afternoon, was observed at Tangier. The synoptic chart for 1800 is reproduced in Fig. 1. Duststorms were reported at that time from the interior and Mediterranean coast of Morocco.

Conditions at Gibraltar during the early afternoon were generally cloudy with scattered showers and light variable winds. At 1500 the wind changed abruptly to south-south-westerly and increased to 10–20 kt. After 1800 the wind freshened rapidly, reaching a maximum of 32 kt. with gusts to 60 kt. by 1900. Visibility at first was generally 7–10 miles but thickening haze after 1700 caused a deterioration to 2 miles. The main body of dust arrived at 1830 and the visibility was at once reduced to 400 yd. Frontal rain commenced at 1855 and, shortly afterwards, the visibility improved to 2 miles.

The 1345 Gibraltar upper air temperature observations showed an inversion from 950 to 920 mb. Above this level, temperature decreased at the rate of 4°F./1,000 ft., and it seems probable that over French Morocco, where screen temperatures of over 75°F. were reported, the lapse rate equalled or exceeded the dry adiabatic from the surface to 6,000 ft.

Conditions favourable for the development of duststorms over French Morocco are not uncommon at this time of the year but it is phenomenal for so much dust to be carried so far north. A possible explanation is that the unseasonal very dry weather over Morocco during the four months before this event resulted in an unusually loose top soil in many areas, which was easily lifted and disturbed by strong winds.

A. WARD

Gibraltar, December 7, 1950

Ablation in the Scottish Highlands

In his letter on this subject in the February issue, Mr. H. H. Lamb states that he is interested in the probable effect of rainfall on ablation, as distinct from air temperature. Fortunately observations of rainfall were included in the survey.

Measurable rainfall was observed on 13 days during the period covered by the survey, and the daily amounts can be placed into four groups, with a minimum of four observations per group. The average daily ablation associated with each is given in the following table:—

			inches	
Daily rainfall	trace	0·01–0·04	0·04–0·10	>0·10
Daily ablation	4·65	3·22	2·32	3·90

The number of available observations is admittedly small, but there is a distinct indication of greater ablation associated with the heaviest rainfall group, irrespective of temperature. The greatest daily rainfall was 0·344 in. on the 20th, when the associated ablation was 3·7 in., the total fall for the whole period being 1·559 in.

It would seem that in summer the least ablation occurs on days with prolonged drizzle and hill fog.

D. L. CHAMPION

47 Norrys Road, Cockfosters, Herts., May 14, 1951

Ablation of snow deposits

Mr. H. H. Lamb raises the interesting suggestion that warm rain, even in winter, may be a more effective agent of ablation than spells of warm, dry weather. From my study of Y Ffos Ddyfn, on Carnedd Llewelyn, consequent on the researches of the late J. R. Gethin Jones, I think he has come to the right conclusion. No encampments have been made to measure daily rates of ablation, but sufficient is known to show how effective warm rain is in melting the snow. This was particularly in evidence in 1947 when, despite the excessive accumulations during the preceding severe winter, the winter snow had all gone by May 22, following a warm and rainy April and May.* In contrast, in 1919 the snow lingered until July 2, after a much more moderate winter, and it survived a warm May—but the spring months were dry, with little warm rain.

Mr. Lamb is also correct about warm rain in the winter. For instance, in 1912 the snow lay only until April 26; this was clearly the result of excessive rainfall with temperatures well above normal in the March of that year.

I suspect that there is another factor, which Mr. Lamb has not mentioned. Y Ffos Ddyfn is a gully which faces nearly south; in the early summer or late spring the dwindling snow-bed is well sheltered from winds from all quarters except southerly, and it is notable how in years of late survival of the snow that there has been a scarcity of southerly winds during the last few weeks of the snow-bed's existence.

S. E. ASHMORE

11 Percy Road, Wrexham, May 25, 1951

NOTES AND NEWS

Funnel cloud at Palisadoes, Jamaica

At 1.45 p.m. on December 9, 1950, I observed a cone-like appendage from a cumulonimbus cloud about 12 miles north-west of the station. The cloud base was 3,000 ft. and its top 12,000 ft. There was a slight shower at the time from the cloud.

This cone-like appendage appeared slightly to the rear of the shower and its behaviour was interesting to watch. The first half of its length appeared to have been oblique, that is in relation to the cloud, while the rest of it was more or less vertical. It oscillated greatly in length, sometimes over 2,000 ft. (approximately) while at times it was much shorter. At one time it actually touched the very low hills under it. During all this time it maintained the shape previously described. It lasted for 10 min.

Half an hour later, the cloud tops rose higher and broke through a layer of altocumulus and the shower became more general in character.

A. L. CROSDALE

At the time of the waterspout which I saw myself, there was an almost stationary cold front lying across Jamaica. The low cloud which had been 1 okta of cumulus and stratocumulus over the mountains began to build up to the west and by 3.0 p.m. was 5 oktas in this area. The upper winds were light NE., less than 5 m.p.h. to 15,000 ft. Light showers were frequent to the

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*ASHMORE, S. E.; The late-surviving snow-bed on Carnedd Llewelyn. *J. Glaciol., London,* **1**, 1948, p. 205.

north-west and west of the station, and at 6.0 p.m. there was a slight one at Palisadoes after which the clouds dispersed rapidly.

The peculiar point about this phenomenon was that it occurred to the rear of the light shower, not in the shower, whilst the cloud was not a vigorous one by tropical standards. I have made inquiries of any damage or heavy deluge in the area concerned but it is possible that the active section occurred over the bush, sparsely inhabited and covered by scrub, so it would pass unnoticed.

I presume the phenomenon was more in the nature of a weak tornado rather than a waterspout.

R. K. PILSBURY

Abnormal rainfall, Trinidad and Barbados

The Senior Meteorological Officer, Piarco, Trinidad, reports that the rainfall in Barbados and Trinidad for February 1951 (the dry season) has been abnormally high and the damage to crops in Trinidad has been extensive. At one stage it was anticipated that most of Trinidad's sugar crop would be lost and his Office was inundated by inquiries from sugar planters, the Press etc. Preliminary data indicate that the Barbados rainfall is the highest for February for a hundred years whilst the Trinidad rainfall is 50 per cent. above the highest for ninety years.

Waterspouts at West Kirby, Cheshire and Llandudno, Caernarvon

Rev. E. Robinson, climatological observer at West Kirby, reports as follows: "Three separate waterspouts were observed moving in a westerly direction off the West Kirby shore at 1830 G.M.T. on Friday, April 27, 1951. They were travelling rapidly. At the same time the wind force rose with great gusts accompanied by heavy hail and sleet at this station, and for a mile or two inland."

Mr. Glyn A. Roberts, observer at Llandudno, reports that two waterspouts were seen off Llandudno at 0645 G.M.T. on the same day. Rain and hail fell from the cloud from which the waterspouts were hanging. The larger of the two waterspouts passed over the beach on to farm land and broke up. It is stated to have had a height of 100–150 ft. and a track width of 20–60 ft.

The British Isles were in a fresh polar air stream at the time and squally showers of rain, hail or sleet from cumulonimbus clouds were occurring all over the country. The waterspouts were not associated with a definite front.

Extreme upper air temperatures over the British Isles

In a letter published in the November 1950 *Meteorological Magazine* Mr. Murray quotes the very low temperatures at 700 mb. and 500 mb. over Leuchars on April 25, 1950, as being probable records for that month for south-east Scotland. This conclusion is based on a comparison of the recorded temperatures with minimum values given by Miss F. M. Jones, which were, however, obtained from *ballon-sonde* ascents.

A detailed examination of extreme temperatures recorded during radio-sonde ascents over the British Isles from about 1942 to 1946 was made in the Upper Air Section of the Meteorological Office some time ago in order to have reliable values for inquiries for such data. It was found that extremes taken from

EXTREME UPPER AIR TEMPERATURES RECORDED BY RADIO-SONDE IN THE BRITISH ISLES

Period.—June 1943–1946 (maximum), 1942–46 (minimum)

Height	MAXIMUM TEMPERATURES								MINIMUM TEMPERATURES								Height
	Reliable values				Unconfirmed values				Reliable values				Unconfirmed values				
	Temp.	Station	Date	Time	Temp.	Station	Date	Time	Temp.	Station	Date	Time	Temp.	Station	Date	Time	
mb.	°F.			G.M.T.	°F.			G.M.T.	°F.			G.M.T.	°F.			G.M.T.	mb.
40	-28	Lerwick Larkhill	30-12-45 16-6-44	0000 1200	...	...	...	...	-104	Penzance	5-12-46	0600	-107±2	Stornoway	*-3-45	0600	40
60	-37	Lerwick	3-7-45	1200	...	...	...	...	-107	Stornoway	16-1-45	0000	...	...	...	...	60
80	-33	Leuchars	28-6-44	1200	...	...	...	...	-107	Stornoway	16-1-45	0600	...	...	...	...	80
100	-35	Lerwick Leuchars	14-8-43 28-6-44	0600 1200	-33	Lerwick	14-5-45	0600	-103	Fazakerley Lerwick Lerwick Stornoway	1-1-44 9-3-45 22-2-43 16-1-45	0600 0000 2000 0600	-120	Penzance	3-2-46	0600	100
130	-36	Leuchars	28-6-44	1200	...	...	...	...	-106	Downham Mkt.	29-12-44	0000	-113	Penzance	3-2-46	0600	130
150	-29	Lerwick	22-6-43	0000	...	...	...	...	-113	Fazakerley	26-2-43	1200	-121	Fazakerley	1-1-44	0600	150
170	-30	**Lerwick**	9-8-43	0000	-29	Leuchars	1-8-46	1200	-108	Downham M. Fazakerley Lerwick	27-1-44 2-1-44 1-1-45	1800 0600 0000	-110	Fazakerley	1-1-44	0600	170
200	-28	Lerwick	8-8-43	1800	-17	Larkhill	28-9-43	0000	-103	Lerwick	8-3-44	0000	-109	Stornoway	28-12-44	1200	200
300	-9	Fazakerley	8-8-43	0000	...	...	...	...	-87	Downham Mkt.	21-1-45	0600	-92±2	Leuchars	*-1-45	0600	300
400	9	Fazakerley	8-8-43	0900	...	...	...	...	-69	Lerwick Leuchars Stornoway	23-1-45 24-1-45 26-1-45	1800 1800 0000	-77±2	Leuchars	*-2-45	1800	400
500	26	Penzance	8-8-43	1200	...	...	...	...	-50	Stornoway	19-1-45	0600	-52±2	Leuchars	*-1-45	1800	500
600	33	Penzance Penzance	18-8-43 31-8-43	1200 1200	...	...	...	...	-32	Lerwick	27-2-44	0000	...	...	...	...	600
700	51	Penzance	8-8-43	1200	53±2	Stornoway	*-5-44	0600	-14	Lerwick	27-2-44	0000	...	...	...	...	700
800	63	Penzance Larkhill Fazakerley	17-8-43 17-8-43 17-8-43	1200 1800 1800	...	...	...	...	1	Lerwick Stornoway Leuchars Lerwick	27-2-44 19-1-45 19-1-45 11-12-45	0000 1800 1800 1200	...	...	...	...	800
900	71	Fazakerley Fazakerley Larkhill	31-7-43 31-7-43 31-7-43	0600 1200 1200	...	...	...	...	11	Leuchars	29-1-45	0600	...	...	...	...	900

*These dates are not known. The information is extracted from frequency tables with values given in 5-degree ranges.

monthly tabulations could not be considered satisfactory as a scrutiny of ascents giving extremes often revealed that they were unreliable. The table of extremes given on p. 201 was compiled after carefully examining all the ascents quoted; many values were rejected before arriving at these final figures.

The " reliable values " are those which could be accepted with reasonable confidence. The " unconfirmed values " are those which either could not be checked as the original records were not available, or appeared doubtful but could not be rejected with reasonable confidence. For maximum temperatures, however, in particular those at the lowest pressures, this must be interpreted as meaning either that they were considered good ascents by the observing station or that they showed no remarkable deviations from comparable ascents. It is still uncertain to what extent radio-sonde temperatures are affected by insolation and instrumental defects.

Maximum temperatures are those recorded after June 1943; this is approximately the date when an improved radiation shield and longer suspension were brought into use.

It will be seen that the value of −6°F. at 3 Km. was surpassed by a value of −14°F. at Lerwick, and, interpolating between the 600-mb. and 500-mb. extremes, an estimated minimum of −41°F. at 550 mb. is found for north Scotland which is also lower than the 5-Km. value given by Miss Jones.

These radio-sonde values were also recorded during January and February ascents and the Leuchars values given by Mr. Murray may well be records for April.

D. DEWAR

35th Physical Society Exhibition

Meteorological instruments were shown on several stands at the Physical Society's annual exhibition of scientific instruments and apparatus held on April 6–11 at the Imperial College.

Meteorological Office stand

Wind-direction recorder using a single pen, operated by magslip transmission, writing on a 720° chart with north lines at the centre and sides of the chart (see photographs facing p. iii of cover).

Experimental barograph with several improvements such as a means of lowering or raising the aneroid chamber so as to cover pressures down to 750 mb., an adjustable link for altering the scale value, and a time marker which cannot strain the transmission.

Fog-density indicator.—A number of small electric lamps are surrounded by a rectangular arrangement of photo-electric cells. In clear air no light from the lamps is received by the photo-electric cells, but light scattered by fog does reach the photo-electric cells and the intensity of the photo-electric cell output is a rough measure of the fog density. The instrument is intended to be flown on a captive balloon and the cable to the balloon carries the photo-electric cell output.

Photo-electric visibility meter[1] working over a range of a few yards. A puff of cigarette smoke in the beam is used to simulate fog.

Frost-point hygrometer with photo-electric detection of the frost point and automatic control of thimble temperature.[2]

Messrs. Casella's stand

Direct distant-reading sensitive anemometer having a Sheppard cup anemometer with a shutter fixed to the spindle arranged to vary the light falling on a photocell as the shaft turns. By varying the number of apertures in the shutter the scale can be spread over various parts of a range from ½ to 100 m.p.h.

Aspirated psychrometer using thermocouples.—This instrument is fitted with thermocouples instead of the usual thermometers and is electrically aspirated. A constant wetting device is provided for the wet " bulb " so that the observer need not be continuously present.

Duvdevani dew gauge.[3]

" *Sword* " *hygrometer* for industrial use.—The " sword " is hollow and contains the hairs to which the air obtains access by holes at the end of the " blade ". The relative humidity is shown on a scale in the handle.

Negretti and Zambra showed a precision aneroid for mining use.

British Electrical and Allied Industries Research Association

Anemometer for measuring gusts.—A small, hollow, perforated sphere is attached to one end of a pivoted rod. Movements of the sphere, due to gusts of wind, are recorded electrically, making use of a transducer. The response time is less than 0·1 sec.[4]

Chemical Defence Experimental Establishment

Photo-electric drop counter.—The passage of a drop through a beam of light produces an electrical impulse at the photo-electric cell. The instrument operates in the drop-size range from several millimetres to 0·25 mm. diameter and counts at rates up to 400 a minute.

Fielden Electronics Ltd

Electronic hygrometer.—The instrument employs thermistors, two dry and one wet. One dry and one wet thermistor function as a normal wet- and dry-bulb hygrometer; the third element is arranged in a special circuit to compensate for changes in ambient temperature so that the instrument records the relative humidity directly.

[1] *Met. Mag., London*, **79**, 1950, p. 114.

[2] *Met. Mag., London*, **80**, 1951, p. 118.

[3] *Met. Mag., London*, **76**, 1947, p. 160.

[4] *Met. Mag., London*, **80**, 1951, p. 115.

Shielded thermometer mounts

In the photograph facing p. 9 of the January 1951 issue of the *Meteorological Magazine* can be seen small shielded thermometer mounts which were used with minimum thermometer and distant-reading thermograph bulbs to measure temperatures under glass cloches. Such a small, cheap, and portable screen has been found necessary for many such experiments* in agricultual meteorology.

The main virtue of the standard Stevenson screen is that it creates a standard exposure which can be reproduced elsewhere. It does not claim to ensure the recording of the true air temperature; the readings therefrom may be untrue, but at least they are uniformly untrue.

During the months August to December 1949, experiments were carried out at Bristol to test the efficiency of these shielded mounts, both in comparison with Stevenson screens and between themselves.

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*For example: SMITH, L. P.; Temperature under Dutch lights. *Met. Mag., London*, **80**, 1951, p. 50

A Stevenson screen, containing two minimum thermometers, and two mounts, each containing one minimum thermometer, were set up in identical exposures over a grass lawn. During the experiment the readings of the index and the meniscus were taken; individual thermometers were interchanged after each reading, and the order of reading was reversed each day.

The results so obtained were analysed statistically and the following conclusions drawn:—

When similarly exposed on a homogeneous site, the readings of night minimum temperatures of spirit thermometers in the shielded mounts rarely differed by more than two or three tenths of a degree; this is the order of difference which is obtained from Stevenson screens similarly compared.

The minimum recorded in a shielded mount was lower than that recorded in a Stevenson screen by about ¾°F. on cloudy or windy nights and about 1°F. on radiation nights. The maximum discrepancy was about 2°F.

For spot readings of day temperatures differences of the order of ½°F. between thermometers in shielded mounts can be regarded as significant.

In cloudy conditions the spot day readings from shielded mounts can be from ½° less to 1½°F. more than those from a Stevenson screen. In bright sunshine the readings were rarely less than the standard ones and could be as much as 2½°F. more. On a hot sunny midsummer day the difference might be even greater.

In general it may be said that the degree of uniformity of readings from shielded mounts is very similar to that obtained from standard screens. The absolute values are mainly less by night and greater by day, but not by any such amounts that would render their use for field experiments inadvisable, provided that the probable errors in hot sunlight are taken into consideration.

A full account of the experiment will be published elsewhere.

R. W. GLOYNE
L. P. SMITH

New Japanese meteorological publication

The first volume of the new Japanese meteorological publication, *Papers in Meteorology and Geophysics,* of the Meteorological Research Institute, Tokyo, has been received. The papers are all in English.

The volume contains twenty-four papers covering a wide field. These are papers on dynamical meteorology, synoptic meteorology, instruments, statistical analysis of observations, applications of meteorological information in house design, evaporation, radiation, atmospheric electricity and terrestrial magnetism. A particularly interesting paper is Dr. Arakawa's description, based on a number of radio-sonde ascents, of the vertical structure of a typhoon which crossed Japan, passing very near Tokyo in August 1949.

British meteorologists will wish success to the Research Institute and its new periodical.

Present position of the Meteorological Service in Japan

Three-quarters of a century has now elapsed since the Central Meteorological Observatory was established in Tokyo on June 1, 1875.

The record of Directors of the Observatory from that time is:—

Mr. Arai, Ikunosuke, June 1875–March 1891
Mr. Kobayashi, Kazutomo, March 1891–August 1895
Dr. Nakamura, Kiyoo, August 1895–February 1923
Dr. Okada, Takematsu, February 1923–July 1941
Dr. Fujiwhara, Sakuhei, July 1941–March 1947
Dr. Wadati, Kiyoo, March 1947–

Japanese meteorologists received two sad reports in 1950, namely the deaths of Dr. S. Fujiwhara and Mr. W. Oishi, ex-Director of the Aerological Observatory.

Major scientific periodicals or serials now published by Japanese meteorological organizations are:—

Kisho-Syushi (Journal of the Meteorological Society of Japan), 1882–
Geophysical Magazine, published by the Central Meteorological Observatory, 1926–
Papers in Meteorology and Geophysics, published by the Meteorological Research Institute, Tokyo, 1950–
Geophysical Notes, published by the Geophysical Institute, Tokyo University, Tokyo, 1946–
Science Reports of the Tohoku University, 5th Series: *Geophysics*, published by the Geophysical Institute, Tohoku University, Sendai, 1949–
Umi To Sora, published by the Marine-Meteorological Society of Japan, 1921–

The major publications of Japanese meteorological observations are:—

Daily Weather Map, 1883–
Monthly Report of the Central Meteorological Observatory of Japan, 1892–
KishoYoran (*Monthly Geophysical Review*), (excepting 1944–46) 1900–
Aerological Data of Japan, 1947–

Under the Central Meteorological Observatory there are 5 District Central Meteorological Observatories (Tokyo, Osaka, Fukuoka, Sendai and Sapporo), approximately 150 field stations, 4 Marine Observatories (Kobe, Nagasaki, Hakodate and Maizuru), 1 Aerological Observatory (Tateno), 1 Terrestrial Magnetic Observatory (Kakioka), a Training School for Meteorological Observers and a Meteorological Research Institute. The total staff of Central Meteorological Observatory numbers approximately 5,400.

H. ARAKAWA

Geographical Journal

The Geographical Journal for March 1951 contains the text and discussion of Professor Manley's paper " The range of variation of the British climate " read at the Royal Geographical Society's meeting on January 23, 1950.

The first part of Professor Manley's paper deals with the fluctuations of annual mean temperature since 1700, with especial detail for the increase since 1925, and with the probable amplitude of earlier fluctuations of temperature since the " climatic optimum " some 5,000 years ago. The second part deals with the temperature of the last glacial and early post-glacial times in Britain. The information for the period since 1700 is based on instrumental observations, but for earlier times a variety of evidence, meteorological (e.g. the present relation between the height of the snow-line and temperature over western Europe), botanical and geological, is assembled.

The author considers that each of the principal climatic changes, since the maximum of the last glaciation, was associated with a rise or fall in the mean temperature of the summer of only 2° or 3°F., and that the changes are attributable to the persistence over shorter or longer periods of high- or low-index circulation patterns.

A second paper of meteorological interest in the same number is by Brigadier R. A. Bagnold, F.R.S., on " Sand formation in southern Arabia " in which the formation of the sand dunes is related to wind.

G. A. BULL

REVIEWS

Die Intensität der zonalen Zirkulation in der freien Atmosphäre aussertropischer Breiten. By Hermann Flohn. *Beitr. Geophys., Leipzig,* **60**, 1944, pp. 196–209.

This paper by Flohn gives interesting figures from an analysis of the best observational material available in Germany up to 1943–44. Tables I–III are quoted from the paper.

TABLE I—MEAN ZONAL COMPONENTS AT THE 5-KM. LEVEL IN VARIOUS LATITUDES

	Mean zonal component at latitudes (N.)					
	30°	40°	50°	60°	70°	80°
	knots					
Winter (December–February)	32	38	27	21	10	3
Summer (June–August) ...	8	20	17	10	10	6

Scalar values of individual wind speeds observed are greatest over the eastern sides of the oceans and north of 50°N., but they are not purely westerly. The strongest zonal components and the maximum occurrence of purely W. winds are in lower latitudes over the western sides of the oceans and east coasts of America and Asia (frontogenetic areas), determining the location in the hemisphere of the strongest mean zonal components in 35–45°N.

The European sector actually shows its highest zonal components of mean velocity in summer, because in winter the prevailing upper winds are northerly or north-westerly there.

TABLE II—SEASONAL VARIATION OF MEAN ZONAL COMPONENTS IN THE 5-KM. LEVEL AT 40°N.

	Mean zonal component in various sectors		
	North America 75–125° W.	Europe 5° W.–35 E.	Northern hemisphere
	knots		
Winter (December–February) ...	46	13	38
Summer (June–August)	21	16	20

The constancy of westerlies in the lower latitudes over eastern Asia and the United States is shown by some remarkable winter values of mean vector wind velocity: Japan (36°N.) at 4 Km. W., 46 kt.; at 10 Km. W., 140 kt. (260 Km./hr.); New England, U.S.A. (40–45°N.) at 4 Km. W., 37 kt. Flohn remarks that on account of the semi-permanent strong upper westerly flow stationary anticyclones rarely occur over eastern North America and, presumably, over eastern Asia; most highs travel almost as fast as depressions across these regions.

Conditions are presumed to be different in many respects in the southern hemisphere due to absence of monsoonal heating and cooling effects. Flohn, who worked up the results of the *Schwabenland* expedition of 1939, uses data for the South-Atlantic sector to illustrate these differences.

TABLE III—COMPARISON BETWEEN NORTHERN AND SOUTHERN HEMISPHERES OF THE MEAN ZONAL COMPONENTS IN 35–65° LATITUDE

Height	Mean zonal component			
	Northern hemisphere		Southern hemisphere	
	Winter	Summer	Winter	Summer
	knots			
5 Km.	27	15	(46)	36
Surface	3	1·6	20	17
Westerly thermal component (0–5 Km.) ...	24	13	26	19

It is interesting that the zonal components of circulation in the southern summer exceed those for the northern winter and that there is much less variation from summer to winter in the southern than in the northern hemisphere.

The greater thermal components of zonal circulation in the south are clearly due to the lower temperature in the Antarctic than in the Arctic troposphere, particularly in summer. South of 50°S. precipitation falls predominantly as snow even in summer—at least in the Atlantic-Ocean, Indian-Ocean and Australian sectors.

The most striking difference between the northern and southern hemispheres is, however, between the mean values for zonal components of surface winds and also, of course, the surface pressure gradients.

Meridional circulations do occur in the southern hemisphere, though less often than in the northern. Argentine meteorologists have drawn attention to the persistence of a trough in the upper wind flow east of the Andes which is the most formidable barrier in the world to the free zonal flow[1]. This trough may be considered to play the part of an anchor in the wave-train of the upper westerlies. Nevertheless it is not quite always present. The strongly predominant zonal character of the southern-hemisphere circulation is shown beyond doubt by Flohn's figures.

The grand-scale heat interchange between low and high latitudes seems to have a different character in the two hemispheres. In the north there is evidence that the greatest heat exchanges are achieved in an orderly manner by meridional circulations and other patterns involving the development of blocking anticyclones as cut-off warm eddies in high latitudes[2]. In the southern hemisphere such blocking anticyclones hardly occur at all. Estimates quoted by Flohn show that rainfall between 35° and 65°S. averages nearly one third greater, and between 50° and 55°S., nearly one half greater than in corresponding northern latitudes. These differences are of course bound up with the different proportions of land and sea in the corresponding zones of the two hemispheres; and as a result thereof, if we may accept the estimated rainfall figures, the occlusion process, by more or less disorderly variations of the westerlies associated with passing depressions, appears capable of transporting larger quantities of heat towards high latitudes in the southern hemisphere than in the northern. Periods of increased thermal gradient between tropics and poles, due to whatever cause, may therefore result in increased zonal flow in the southern hemisphere and decreased zonal flow with development of blocking anticyclones in the northern hemisphere.

H. H. LAMB

REFERENCES

1. BOFFI, J. A.; Effect of the Andes Mountains on the general circulation over the southern part of South America. *Bull. Amer. met. Soc., Lancaster Pa.*, **30**, 1949, p. 242.

2. ELLIOTT, R. D., and SMITH, T. B.; A study of the effects of large blocking highs on the general circulation in the northern-hemisphere westerlies. *J. Met., Lancaster Pa.*, **6** p. 67.

An investigation on some aspects of the effect of land and sea breezes. By F. Balkema, *Meded. ned. met. Inst., De Bilt*, B, **2**, No. 13, 1950. pp. 50. *Illus.*, Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage and Utrecht, Price *fl:* 1.50.

This investigation is the first in which a special study is made of land and sea breezes over Holland. After a general introduction, the author analyses 10 years' wind observations for IJmuiden on the Dutch coast. Diagrams of the vector mean wind at each hour of the day for each month of the year show a marked diurnal variation of wind, particularly during the summer months.

As a measure of the differential heating of the air over land and sea, the author computes values of the mean daily " relative insolation " from observations of insolation at De Bilt, 35 miles inland from IJmuiden, but unfortunately he fails to give a clear definition of the term " relative insolation".

The wind observations are classified according to the relative insolation and the gradient wind, and a series of diagrams shows that, in general, increased insolation results in an increased on-shore wind component during the day, suggestive of a sea-breeze effect. Exceptions occur with gradient winds between north-east and east when there is an increased off-shore component. The latter effect is shown to be due to the formation of a thermal depression over south-east Holland.

The author is unable to find any close correlation between the magnitude of the sea-breeze effect, the stability of the air, and the difference in temperature of the air over land and sea, and concludes that the sea-breeze effect is more closely correlated with the relative insolation. Nevertheless, Table VI does show some evidence of a correlation between the pronounced sea breezes and increased stability, which the author appears to have disregarded and which might repay further investigation.

In later chapters, the author gives a comprehensive account of recent theoretical investigations into the structure of the sea breeze, with particular reference to the effect of lapse rate. This proved very difficult to treat theoretically, and no firm conclusions were reached.

To the reviewer, there appear to be few advantages in using values of relative insolation as a measure of the differential heating of the air. As the author points out, the amount of heat supplied to the atmosphere will, for the same insolation, vary according to the water content of the soil and the type of vegetation. In practice, therefore, the daily variation of the temperature difference of the air over land and sea, meaned throughout the convective layer, is a better guide.

This is an interesting work, but unfortunately spoiled by a stilted translation which gives rise to a great deal of obscurity and ambiguity.

ALAN WARD

BOOKS RECEIVED

Tätigkeitsbericht, 1948–49. Schweizerisches Forschungsinstitut für Hochgebirgsklima und Tuberkulose in Davos, enlarged from *Schweiz, med. Wschr., Basel,* Jg. 80, 1950, p. 239. 8¼ in. × 5¾ in., pp. 13, Benno Schwabe & Co., Basel, 1950.

Die Klimaverhältnisse von Wiesen. By W. Mörikofer. *Jber. naturf. Ges. Graubünden, Chur,* **82**, 1950, pp. 53–88.

Theoretisches und Konstruktives zur Messung der Abkühlungsgrösse. By H. Wierzejewski. *Arch. Met. Geophys. Bioklim, Wien,* B, **2**, 1950, pp. 65–85.

Tagesgang und Komponenten der Abkühlungsgrosse. By Charlotte Henneberger. *Arch. Met. Geophys. Bioklim., Wien,* B, **2**, 1950, pp. 86–119.

L'importance des particularités du climat local pour les stations climatiques. By W. Mörikofer. *Věstn. čsl. fysiatrické společn. Praha,* Cís. 1–6, 1948, pp. 28–34.

Der Luftdruckvariograph als Hilfsmittel bei der Wetteranalyse. By Walter Schüepp. *Verh. schweiz. naturf. Ges., Lausanne,* 1949, pp. 113–14.

A study of the distribution of rainfall in the peninsula associated with some pre-monsoon storms. By P. N. Boothalingam and V. Srinivasan. *Sci. Notes India met. Dep., Delhi,* **11**, No. 132, pp. 9–16. *Illus.* Manager of Publications, Delhi, 1950, Price: *Rs.* 3/14/– or 6*s.* 3*d.*

L'osservatorio meteorico di Orvieto. By C. Lo Iacono, *Riv. aero., Roma,* **26**, Nr. 12, pp. 895–903. *Illus.* Associazione Culturale Aeronautica, Roma, 1950.

OBITUARY

Miss Agnes J. Tolmie, O.B.E.—The Toronto *Weekly Star* of March 22, 1951, records the death of Miss Tolmie, who had been an observer at Southampton, Ontario, for the Canadian Meteorological Service since 1872. She had been in full charge of the synoptic reporting station at Southampton since 1917 and made reports three times a day until very recently. She was awarded the O.B.E. for her work during the second World War.

Miss Tolmie was well known to the staff of the British Meteorological Office set up during the war at the Air Navigation School at Port Albert, 50 miles to the south-south-west. Southampton was the only reporting station north of Port Albert and its reports were very valuable when frontal systems were approaching from north or north-west.

NEWS IN BRIEF

Mr. J. C. W. Day of 15 Dartmouth Avenue, Walsall, is anxious to add a rain recorder to the equipment of his climatological station and will be pleased to hear from anyone willing to dispose of a recorder at a reasonable price.

METEOROLOGICAL OFFICE NEWS

Sports and Athletics.—*The Air Ministry Sports* were held at the White City Stadium on June 12 in excellent weather. The Office again won the Jones Cup for the highest number of points and the Halahan Shield for the tug-of-war. Noteworthy individual performances were those of Mr. R. J. Garner, who won the 100 yards and the 220 yards championships and Miss K. N. Newman (an Assistant trainee), who won the 100 yards ladies' championship and the 220 yards ladies' scratch race.

The period during which points are allotted in the competition for the Bishop Shield ended with the annual sports meeting, and for the third year in succession the Office were the winners. The main contributors to this were the swimmers who won every race, the athletes who gained so many points at the sports meeting, and the Harrow ladies' netball team who won the Air Ministry tournament for the third successive year.

The Office is indebted to Mr. H. A. Scotney for the time and trouble which he devotes to fostering the keen sporting spirit which plays so large a part in the achievement of our successes.

Cricket.—Cricket enthusiasts will be interested to know that the Central Forecasting Office cricket team (captain, Mr. H. E. Snow), emboldened by local successes, challenged Headquarters, London, to select a team for a " needle " match to be played at Dunstable. With wide choice of players, London was able to include Messrs. C. W. Lamb and H. G. Garnett in their team, the former acting as captain.

The match was played at Dunstable on June 4 before a crowd of spectators, in perfect weather (though not on a perfect wicket). The challengers, who won the toss and went in to bat first, were all out for 36. The London team won the match with a total of 132.

The outstanding performances of the afternoon were the wicket-keeping of C. F. Hawson for the Central Forecasting Office, the bowling of G. Needham for London and the batting of H. G. Garnett, who made a total of 50 runs for London before retiring.

Spectators and players alike declared the match an unqualified success and it is hoped that it will be the forerunner of many similar events.

Golf in Germany.—Members of the staff who play golf will be interested to learn that the Royal Air Force in Germany have an excellent nine-holes golf course located at H.Q., B.A.F.O., Bad Eilsen, and that civilian meteorological staff have the privilege of becoming full members of the club. Several members of the staff have had notable successes in various club and Command competitions, and have also represented the Royal Air Force in Germany in matches with the Army, the Control Commission and with American golfers in the United States Zone. The Chief Meteorological Officer, Mr. R. Cranna, has recently been elected captain of the club.

WEATHER OF MAY 1951

Mean pressure was over 1020 mb. in the area north of the British Isles, including Iceland and the east coast of Greenland. Mean pressures between 1015 and 1020 mb. extended over an area including the north-east Atlantic, most of the British Isles and Scandinavia; similar mean pressures existed over the Atlantic south of latitude 45° N. and in Portugal and Morocco. Mean pressures were mainly between 1010 and 1015 mb. over Europe, north and west Africa and most of North America.

The excess of pressure was most marked in the area north of the British Isles, where it was between 5 and 10 mb. Pressure over Europe was below normal, the deficits varying between 2 and 5 mb.

Mean temperatures were between 40° and 50° F. in the British Isles and Scandinavia, between 50° and 60° F. in Europe, 60° to 70° F. in the Mediterranean area and between 75° and 95° F. in north and west Africa. In the United States mean temperatures varied from 55° F. in the north to 75° F. in the south.

Mean temperature in Europe was between 2° and 5° F. below normal.

In the British Isles the weather was cool, with winds from between north and east predominating. Broadly speaking it was dry and sunny in the north-west and north but wet and rather dull in the south and east.

In the opening days a small depression off Denmark moved west across south Scotland and then swung south-west to south. Rather heavy rain fell in some areas on the 1st, while scattered thunderstorms occurred from the 1st to the 3rd; snow or sleet fell in many districts of Scotland on the 1st. On the 4th a trough of low pressure over France moved slowly north and was associated in England with heavy rain in places and local thunderstorms (2·15 in. at Bradford on the 4th and 2·30 in. at Nidderdale, Yorkshire, on the 5th). In Scotland, however, the weather was dry and sunny. On the 7th a depression over France moved north-east to Germany, while a small secondary disturbance moved south over western Scotland; a spell of cold N.–NE. winds prevailed with local slight rain or snow. Meanwhile a belt of high pressure was situated to the west and north-west of the British Isles and subsequently the centre off north-west Scotland moved slowly south-east over the British Isles and later withdrew south-westward. A period of dry cold weather ensued and lasted until the 15th, when a cold front moving south-west across Great Britain caused some rain in most places. This was, however, only a temporary break in the dry spell as, on the 16th, another anticyclone developed to the north of Scotland and moved southward to the North Sea. The weather was dry from the 16th to the 18th, apart from some rain in the south of England. A change of type occurred on the 19th, when the British Isles began to come under the influence of a complex depression over the Atlantic south of Greenland. Small secondary depressions associated with this system moved north or north-east over the British Isles and a spell of milder, unsettled weather prevailed with rain and local thunderstorms. Temperature rose to 70° F. at a number of stations in England on the 24th and 25th and touched 74° F. at Camden Square, London, on the 24th and at Hull on the 25th. On the 26th and 27th a depression moved north over France to east England, thence west across the Midlands and south-south-west to the mouth of the English Channel; heavy rain and rather widespread thunderstorms occurred on the 26th and fairly heavy rain in some parts on the 27th. Subsequently an anticyclone off the north of Scotland moved slowly south-south-east and the closing days were dry and sunny on the whole, though it was rather dull, particularly in some eastern districts, on the 29th and 30th. The 31st was the sunniest day of the month at many places (16·0 hr. at Dyce in Aberdeenshire) and temperature rose to 70° F. at a number of places in the west and north of Scotland.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	74	22	−2·2	140	+2	88
Scotland	71	21	−1·5	63	−7	124
Northern Ireland ...	68	29	−2·1	72	−4	114

RAINFALL OF MAY 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·12	120	*Glam.*	Cardiff, Penylan ...	2·51	102
Kent	Folkestone, Cherry Gdn.	2·15	128	*Pemb.*	Tenby, The Priory ...	2·29	100
„	Edenbridge, Falconhurst	2·11	113	*Card.*	Aberystwyth	3·33	160
Sussex	Compton, Compton Ho.	2·80	126	*Radnor*	Tyrmynydd	3·71	108
„	Worthing, Beach Ho. Pk.	2·36	143	*Mont.*	Lake Vyrnwy	3·60	112
Hants.	Ventnor, Cemetery ...	3·01	173	*Mer.*	Blaenau Festiniog ...	1·88	33
„	Bournemouth	2·57	146	*Carn.*	Llandudno	3·09	174
„	Sherborne St. John ...	2·95	152	*Angl.*	Llanerchymedd ...	3·03	129
Herts.	Royston, Therfield Rec.	3·06	158	*I. Man*	Douglas, Borough Cem.	3·90	156
Bucks.	Slough, Upton	2·23	133	*Wigtown*	Port William, Monreith	1·99	85
Oxford	Oxford, Radcliffe ...	2·10	112	*Dumf.*	Dumfries, Crichton R.I.	2·45	89
N'hants.	Wellingboro', Swanspool	3·47	179	„	Eskdalemuir Obsy. ...	2·19	66
Essex	Shoeburyness	1·96	151	*Roxb.*	Kelso, Floors	2·87	149
„	Dovercourt	2·09	150	*Peebles*	Stobo Castle	2·88	127
Suffolk	Lowestoft Sec. School ...	...	...	*Berwick*	Marchmont House ...	2·99	121
„	Bury St. Ed., Westley H.	2·27	125	*E. Loth.*	North Berwick Res. ...	2·90	146
Norfolk	Sandringham Ho. Gdns.	2·71	148	*Midl'n.*	Edinburgh, Blackf'd. H.	3·04	148
Wilts.	Aldbourne	3·03	154	*Lanark*	Hamilton W. W., T'nhill	1·46	61
Dorset	Creech Grange... ...	3·20	157	*Ayr*	Colmonell, Knockdolian	2·01	79
„	Beaminster, East St. ...	2·81	136	„	Glen Afton, Ayr San ...	3·12	104
Devon	Teignmouth, Den Gdns.	2·62	143	*Bute*	Rothesay, Ardencraig ...	2·73	90
„	Cullompton	2·66	123	*Argyll*	Morvern (Drimnin) ...	1·00	31
„	Ilfracombe	2·93	142	„	Poltalloch	·59	21
„	Okehampton, Uplands	5·16	192	„	Inveraray Castle ...	1·27	32
Cornwall	Bude, School House ...	3·62	197	„	Islay, Eallabus	1·09	41
„	Penzance, Morrab Gdns.	3.28	148	„	Tiree	·70	28
„	St. Austell	3·40	140	*Kinross*	Loch Leven Sluice ...	2·65	109
„	Scilly, Tresco Abbey ...	2·48	147	*Fife*	Leuchars Airfield ...	1·91	98
Glos.	Cirencester	2·92	142	*Perth*	Loch Dhu	2·50	56
Salop	Church Stretton ...	3.32	131	„	Crieff, Strathearn Hyd.	2·27	91
„	Shrewsbury, Monksmore	3·15	162	„	Pitlochry, Fincastle ...	1·88	89
Worcs.	Malvern, Free Library	3·55	164	*Angus*	Montrose, Sunnyside ...	1·42	70
Warwick	Birmingham, Edgbaston	3·63	170	*Aberd.*	Braemar	1·72	72
Leics.	Thornton Reservoir ...	3·29	164	„	Dyce, Craibstone ...	1·32	52
Lincs.	Boston, Skirbeck ...	2·95	168	„	Fyvie Castle	1·19	46
„	Skegness, Marine Gdns.	3·05	179	*Moray*	Gordon Castle	·98	46
Notts.	Mansfield, Carr Bank ...	3·20	151	*Nairn*	Nairn, Achareidh ...	·59	34
Derby	Buxton, Terrace Slopes	2·60	84	*Inverness*	Loch Ness, Garthbeg ...	·93	37
Ches.	Bidston Observatory ...	2·85	150	„	Glenquoich	·73	13
Lancs.	Manchester, Whit. Park	...	...	„	Fort William, Teviot ...	·50	13
„	Stonyhurst College ...	1·63	57	„	Skye, Duntuilm ...	·42	15
„	Squires Gate	2·83	136	*R. & C.*	Tain, Tarlogie House ...	1·08	52
Yorks.	Wakefield, Clarence Pk.	4·34	220	„	Inverbroom, Glackour ...	1·97	66
„	Hull, Pearson Park ...	4·50	233	„	Applecross Gardens ...	1·97	61
„	Felixkirk, Mt. St. John	4·93	262	„	Achnashellach	·83	20
„	York Museum	3·71	186	„	Stornoway Airfield ...	·96	40
„	Scarborough	4·31	226	*Suth.*	Loch More, Achfary ...	2·61	59
„	Middlesbrough... ...	4·29	223	*Caith.*	Wick Airfield	·46	22
„	Baldersdale, Hury Res.	2·83	110	*Shetland*	Lerwick Observatory ...	·30	14
Norl'd.	Newcastle, Leazes Pk....	3·59	181	*Ferm.*	Crom Castle	1·73	62
„	Bellingham, High Green	2.38	99	*Armagh*	Armagh Observatory ...	1·49	63
„	Lilburn Tower Gdns. ...	3·67	159	*Down*	Seaforde	3·64	138
Cumb.	Geltsdale	2·08	81	*Antrim*	Aldergrove Airfield ...	1·33	59
„	Keswick, High Hill ...	3·08	97	„	Ballymena, Harryville...	1·45	51
„	Ravenglass, The Grove	1·73	62	*L'derry*	Garvagh, Moneydig ...	1·71	67
Mon.	Abergavenny, Larchfield	3·40	127	„	Londonderry, Creggan	1·24	47
Glam.	Ystalyfera, Wern House	3·11	89	*Tyrone*	Omagh, Edenfel ...	1·62	63

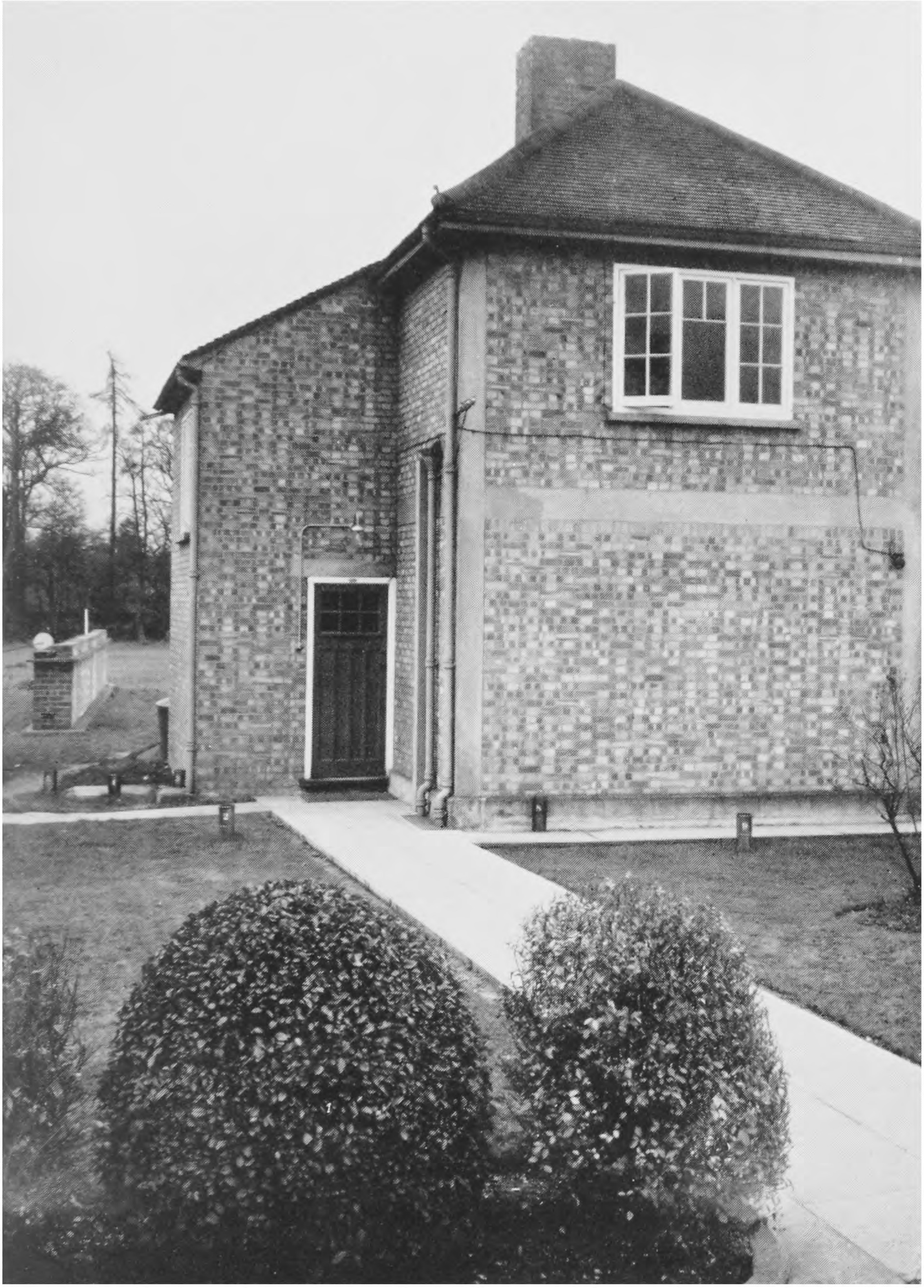
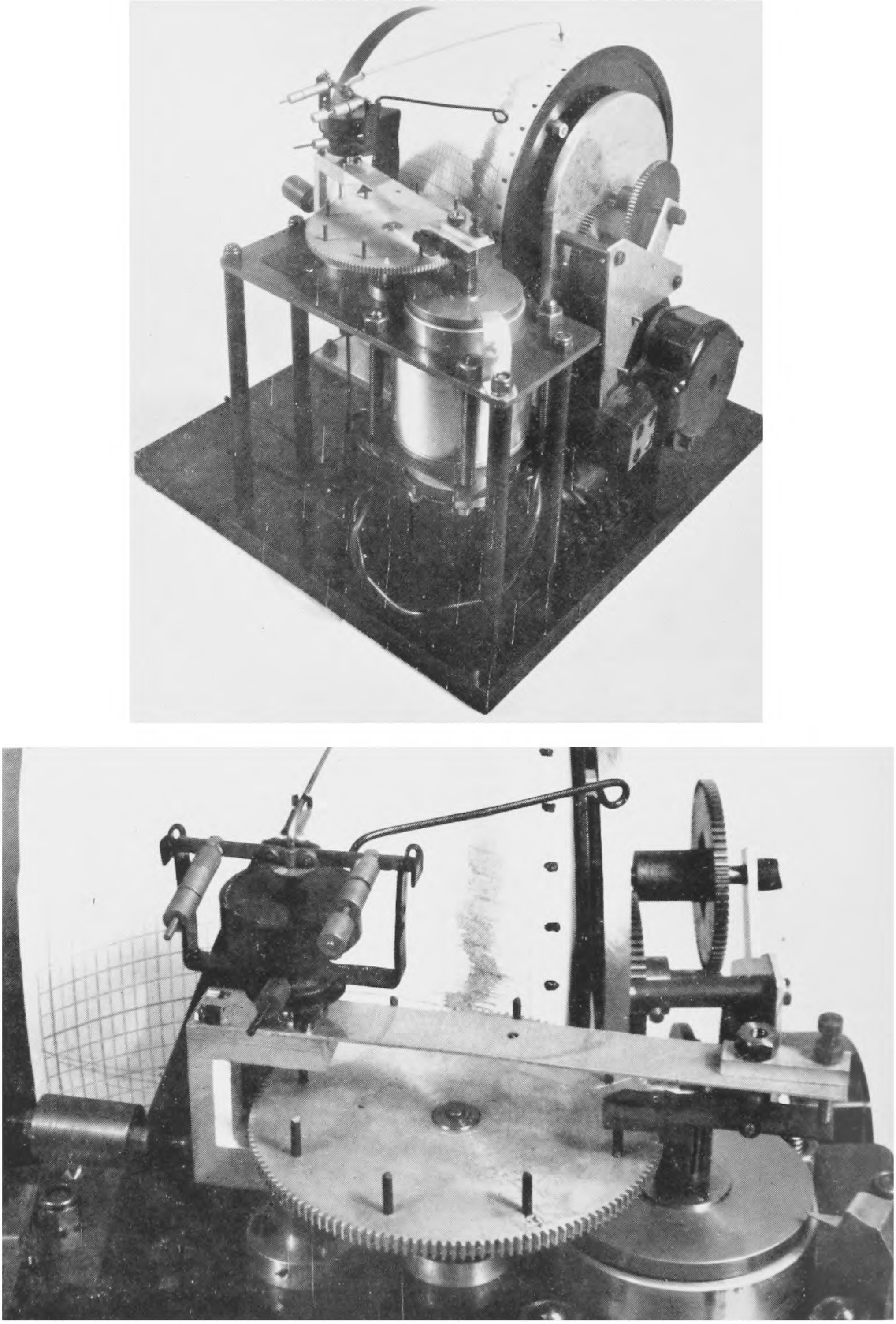


FIG. 2—EXPERIMENTAL HOUSE SHOWING SOME OF THE RAIN-GAUGES

Gauge 1 was only placed between gauges 3 and 5 temporarily



WIND-DIRECTION RECORDER

The wind direction is reproduced by a self-synchronous motor, part of which can be seen in the near corner of the upper photograph, and is then transmitted to the large toothed wheel (see lower photograph) by 8:1 gearing so that the angular distance between each two of the eight pegs on the toothed wheel represents a complete revolution of the wind vane. One of the pegs (extreme right-hand peg in the lower photograph) slides inside a slot within a hinged block which is connected by a lever mechanism to the pen arm. The north-wind direction is in the middle and right and left edges of the chart. As the pen reaches either edge of the chart, the peg moves out of the slot and allows the slotted block to spring back and engage with the next peg, and the pen continues recording in the middle of the chart.

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FREEZING DAYS IN GREAT BRITAIN

By J. E. BELASCO, Ph. D.

This investigation has arisen out of an inquiry from the Study Committee on Basic Design Temperature for Space-Heating Installations.

This Committee was appointed, at the request of the Minister of Works, by the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institution of Gas Engineers and the Institution of Heating and Ventilating Engineers to investigate the factors governing the choice of basic design external air temperatures for space-heating installations for domestic and other buildings and the allowance (if any) appropriate to different localities and for various types of building.

In the course of their work the Committee were desirous of learning the incidence, during 25 winters, of days with mean temperature of 32° F. or less (these days are here called freezing days) at the following stations where, it was considered, weather had been experienced which might be regarded as representative for the populous areas of Great Britain: Aberdeen (Observatory), Edinburgh (Royal Observatory), Newcastle (Cockle Park), Manchester (Whitworth Park), Birmingham (Edgbaston), Bristol (Long Ashton) and London (Kew Observatory).

It is thought that the results obtained may be of general interest and they are reproduced here with some additional matter.

Definition of a freezing day.—Two types of these days have been considered according to the method of obtaining the mean daily temperature. A " T-freezing day " is one whose mean temperature is below 32·5° F. and is based on the mean of the sum of 24 hourly temperatures read to tenths of a degree. A " T'-freezing day " is one whose mean temperature is below 32·6° F. and is based on half the sum of the maximum and minimum temperatures read to whole degrees and credited to the day of entry, readings being made at the stations at the hours shown in Table VI.

The average values of $T-T'$ at Kew and Aberdeen for T'-freezing days when they were also T-freezing days have been calculated and are given in Table I.

On the average $T-T'$ is small and positive. Its standard error and range are however large. It appears from the examination of individual values of $T-T'$ that the sign and magnitude of $T-T'$ on any day depend upon n, the number of hours during this day that the lowest hourly temperature was exceeded by more than half the difference between the maximum and minimum

TABLE I—AVERAGE TEMPERATURE DIFFERENCE BETWEEN T- AND T'-FREEZING DAYS

Station	Period	Average $T-T'$	Standard error	Extreme range of $T-T'$	Number of occasions
		degrees Fahrenheit			
Kew	Nov. 1925–Jan. 1950	+0·1	±0·84	−3·0 to 4·5	272
Aberdeen	Dec. 1923–Dec. 1947	+0·3	±0·92	−3·7 to 4·0	211

TABLE II—ANNUAL FREQUENCY OF FREEZING DAYS

Winter beginning in the October of the year shown

***T*-freezing days, Kew**

Year	Frequency	Year	Frequency	Year	Frequency	Year	Frequency	Year	Frequency
	days		days		days		days		days
1878	38	1893	14	1908	15	1923	9	1938	9
1879	34	1894	33	1909	5	1924	2	1939	36
1880	19	1895	4	1910	7	1925	15	1940	13
1881	3	1896	11	1911	7	1926	2	1941	28
1882	11	1897	4	1912	1	1927	11	1942	2
1883	0	1898	9	1913	4	1928	26	1943	0
1884	5	1899	13	1914	0	1929	0	1944	16
1885	32	1900	13	1915	4	1930	10	1945	6
1886	31	1901	19	1916	27	1931	8	1946	42
1887	18	1902	10	1917	12	1932	8	1947	4
1888	20	1903	11	1918	9	1933	12	1948	5
1889	15	1904	11	1919	5	1934	1	1949	4
1890	44	1905	4	1920	6	1935	9		
1891	31	1906	14	1921	7	1936	2		
1892	17	1907	9	1922	1	1937	3		

Total number of T-freezing days = 890

***T'*-freezing days**

Year	Kew	Aberdeen	Edinburgh	Newcastle	Birmingham	Bristol	Manchester
				Frequency			
1927	11	8	10	12	16	12	9
1928	28	20	19	26	30	24	21
1929	0	6	8	10	6	2	4
1930	8	15	8	19	13	9	15
1931	8	2	2	7	9	8	7
1932	10	14	10	13	13	9	9
1933	13	1	1	4	11	12	4
1934	2	1	1	10	5	2	2
1935	14	14	17	27	18	11	18
1936	2	1	13	14	12	1	7
1937	6	5	7	9	6	4	5
1938	10	11	12	13	15	5	8
1939	39	18	33	37	40	36	36
1940	15	19	21	28	24	12	13
1941	30	19	26	36	37	25	33
1942	2	5	6	9	6	2	7
1943	0	4	7	10	9	4	4
1944	19	15	11	17	19	15	17
1945	9	10	13	24	17	15	11
1946	45	29	51	47	53	45	39
Total	271	217	276	372	359	253	269

temperatures of this day. Thus at Aberdeen on January 20, 1936, $T-T'=4{\cdot}0^\circ$ F. and $n=18$ hr. while on January 22, 1936, $T-T'=-3{\cdot}7^\circ$ F. and $n=5$ hr.

The magnitude of $T-T'$ is greater at Aberdeen than at Kew. This and the positive sign of $T-T'$ are reflected in the number of T'-days per mille of T-freezing days which at Aberdeen was 1,206 and at Kew 1,126 in the 20 winters, 1927–28 to 1946–47.

Incidence of freezing days.—An examination has been made of T-freezing days at Kew during the 72 winters 1878–79 to 1949–50 and of T'-freezing days at Kew, Aberdeen, Edinburgh, Newcastle, Birmingham, Bristol and Manchester during the 20 winters 1927–28 to 1946–47, winter being defined as the months October to April. The annual variation in the number of freezing days is shown in Table II.

The total number of T'-freezing days in the 20 winters varied from 217 to 372. It would be expected that the variation among the stations of this number would depend upon:

(i) altitude of the station (see Table VI)

(ii) distance inland

(iii) location to east and north of the country (in that cold weather generally comes from the east and north), shelter from east and north, and local topography.

The total number of T'-freezing days at the stations does not suggest that any of these effects predominates. The most marked is that of altitude in that the three stations with an altitude exceeding 300 ft. have a mean number of T'-freezing days of 336 compared with 252 at the four stations below 170 ft.

The annual variation in the number of freezing days was considerable at all stations. The number of T'-freezing days was greatest in the winter 1946–47, that of T-freezing days in the winters 1890–91 and 1946–47. In the seven winters 1909–10 to 1915–16 the total number of T-freezing days at Kew was only about one seventh of that in the seven winters 1884–85 to 1891–92.

From Table II the frequency distribution at each station of the number of winters in ten likely to experience at least a specified number of freezing days has been derived. The results are given in Table III. A chi-squared test has been applied to the frequency distributions at Kew obtained from the T-freezing days in the 72 winters and from the T'-freezing days in the 20 winters. The test shows that the difference between the two distributions is not statistically significant, so that the 20 winters chosen may be considered representative of a long series of winters.

TABLE III—NUMBER OF WINTERS IN 10 WITH AT LEAST A SPECIFIED NUMBER OF FREEZING DAYS

	Type of freezing day	Freezing days											No. of winters
		1	5	10	15	20	25	30	35	40	45	50	
		Frequency in 10 winters											
Kew	T	9·4	7·2	4·9	2·9	1·8	1·7	1·3	0·6	0·3	0·0	0·0	72
Kew	T'	9·0	7·5	5·5	3·0	2·0	2·0	1·5	1·0	0·5	0·5	0·0	20
Aberdeen	T'	10·0	7·5	5·5	3·5	1·0	0·5	0·0	0·0	0·0	0·0	0·0	20
Edinburgh	T'	10·0	8·5	6·0	3·5	2·0	1·5	1·0	0·5	0·5	0·5	0·5	20
Newcastle	T'	10·0	9·5	8·0	4·5	3·5	3·0	1·5	1·5	0·5	0·5	0·5	20
Birmingham	T'	10·0	10·0	7·0	5·0	2·5	2·0	2·0	1·5	1·0	0·5	0·5	20
Bristol	T'	10·0	7·0	5·0	3·0	2·0	1·5	1·0	1·0	0·5	0·5	0·0	20
Manchester	T'	10·0	8·0	4·5	3·5	2·0	1·5	1·5	1·0	0·0	0·0	0·0	20

TABLE IV—MONTHLY FREQUENCY OF FREEZING DAYS

	Monthly frequency of freezing days											First freezing day in a winter		Last freezing day in a winter	
	Beginning					Ending									
	Oct.	Nov.	Dec.	Jan.	Feb.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Earliest day	Latest day	Earliest day	Latest day
Kew, T-Freezing days (72 winters*)	0	18	35	13	2	0	2	19	24	22	1	4.11.01	10.2.27	20.12.37	5.4.11
Kew, T'-freezing days (20 winters†)	0	2	13	3	0	0	1	3	6	8	0	17.11.30	22.1.33	20.12.37	15.3.47
Aberdeen, T'-freezing days (20 winters)	0	3	8	5	4	1	1	4	6	8	0	12.11.44	26.2.34	19.12.37	29.3.41
Edinburgh, T'-freezing days (20 winters)	0	2	11	5	2	0	2	2	6	10	0	8.11.27	26.2.34	20.12.37	22.3.37
Newcastle, T'-freezing days (20 winters)	0	3	14	3	0	0	1	1	6	12	0	1.11.34	17.1.33	20.12.37	30.3.41
Birmingham, T'-freezing days (20 winters)	0	3	15	2	0	0	1	2	6	11	0	17.11.30	18.1.33	27.12.37	16.3.46
Bristol, T'-freezing days (20 winters)	0	3	13	2	2	0	3	4	4	9	0	2.11.37	20.2.30	19.12.33 19.12.37	20.3.30
Manchester, T'-freezing days (20 winters)	1	6	10	2	1	0	1	3	7	9	0	26.10.31	14.2.30	20.12.37	20.3.30

* Four winters with no freezing days. † Two winters with no freezing days.

The table shows that there was an even chance each winter of at least 10 freezing days occurring at Kew, Aberdeen, Edinburgh, Bristol and Manchester and of about 15 days at Newcastle and Birmingham.

The frequency at different stations of the different winter months when freezing days began and terminated, and the earliest and latest dates of the first and last freezing days of the winter are given in Table IV.

At all stations freezing days most frequently began in December and ended in March. Over the country as a whole the earliest freezing day may be expected in the last week in October and the last freezing day in the first week in April.

The monthly frequency distribution at Kew of T-freezing days within specified limits in 72 winters is given in Table V.

While January had the largest total number of these freezing days, the largest number in any winter was in December and February.

TABLE V—MONTHLY FREQUENCY OF T-FREEZING DAYS AT KEW IN 72 WINTERS

	Days												Total No. of freezing days
	0	1, 2	3, 4	5, 6	7, 8	9, 10	11, 12	13, 14	15, 16	17, 18	19, 20	21, 22	
	Frequency												
October	72	0	0	0	0	0	0	0	0	0	0	0	0
November	54	11	5	2	0	0	0	0	0	0	0	0	42
December	25	13	15	8	5	3	0	0	0	0	0	1	231
January	15	19	11	9	6	4	2	4	0	1	1	0	315
February	26	15	15	4	2	4	0	2	0	0	0	1	216
March	50	9	5	5	1	2	0	0	0	0	0	0	85
April	71	1	0	0	0	0	0	0	0	0	0	0	1

Temperature of freezing days.—The average winter (December–February) temperature (calculated as half the sum of the maximum and minimum temperatures) and the average temperatures for the 72 winters of T-freezing days at Kew and for the 20 winters of T'-freezing days at all stations are given in Table VI.

As the Study Committee required the average temperature of freezing days for 25 winters, these have been included in the table together with the lowest recorded temperature of a freezing day. It will be seen that the 25 winters available did not all cover the same years, so that the results obtained from them are not strictly comparable.

TABLE VI—AVERAGE TEMPERATURE OF FREEZING DAYS

Station	Height	Period	Freezing days					Hours used	Average winter temperature
			Type	No.	Average temperature				
					Whole period	20 winters 1927–47	Lowest recorded		
	ft.				°F.	°F.	°F.		°F.
Kew	18	Dec. 1878–Jan. 1950	T	890	29·4	...	17·0	0h.–24h.	40·9
Kew	18	Nov. 1925–Jan. 1950	T'	299	29·7	29·7	19·8	0h.–24h.	40·9
Aberdeen	37	Dec. 1923–Dec. 1947	T'	252	29·8	29·5	21·7	0h.–24h.	39·3
Edinburgh	441	Nov. 1925–Jan. 1950	T'	323	30·1	29·9	21·0	21h.–21h.	40·5
Newcastle	325	Nov. 1925–Dec. 1950	T'	444	29·9	29·8	16·0	21h.–21h.	38·3
Birmingham	535	Nov. 1925–Dec. 1950	T'	413	29·6	29·5	18·0	{day max. night min.}	39·5
Bristol	162	Nov. 1925–Dec. 1950	T'	286	29·3	29·3	18·0	9h.–9h.	41·2
Manchester	125	Nov. 1925–Dec. 1950	T'	307	29·8	29·8	19·0	9h.–9h.	39·4

The variation of the mean temperature of T-and T'-freezing days shows little variation from place to place; the range of T' was only 0·6° F., being about one-fifth that of the average winter temperature. There appears to be no relationship between the average winter temperature and that of T'-freezing days nor between the latter and the altitude of the station.

The monthly frequency distribution of freezing days with mean temperature between specified limits for the 72 winters at Kew is given in Table VII and for the 20 winters at Kew and the other stations in Table VIII.

From these tables the probability of occurrence of mean temperatures less than a specified value can be derived. Thus at Kew the probabilities of days with mean temperature below 23·6° F., 28·6° F. and 32·6° F. were, respectively, once in 3½ winters, about four times each winter and about 14 times each winter.

TABLE VII—MONTHLY FREQUENCY DISTRIBUTION AT KEW OF T-FREEZING DAYS WITH MEAN TEMPERATURE BETWEEN SPECIFIED LIMITS

Period: 72 winters, 1878–79 to 1949–50

	Temperature (°F.)															
	31·5 to 32·4	30·5 to 31·4	29·5 to 30·4	28·5 to 29·4	27·5 to 28·4	26·5 to 27·4	25·5 to 26·4	24·5 to 25·4	23·5 to 24·4	22·5 to 23·4	21·5 to 22·4	20·5 to 21·4	19·5 to 20·4	18·5 to 19·4	17·5 to 18·4	16·5 to 17·4
	Frequency															
Nov.	7	14	6	8	1	3	2	0	0	1	0	0	0	0	0	0
Dec.	57	43	32	24	22	16	15	6	7	4	2	1	1	0	0	1
Jan.	68	54	56	38	24	25	12	8	12	3	3	6	4	0	1	1
Feb.	63	40	35	22	16	16	8	7	1	1	0	3	1	1	2	0
Mar.	41	17	13	8	3	1	2	0	0	0	0	0	0	0	0	0
Apr.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE VIII—TOTAL FREQUENCY DISTRIBUTION OF T'-FREEZING DAYS WITH MEAN TEMPERATURE BETWEEN SPECIFIED LIMITS

Period: 20 winters, 1927–28 to 1946–47

	Temperature (°F.)																
	31·6 to 32·5	30·6 to 31·5	29·6 to 30·5	28·6 to 29·5	27·6 to 28·5	26·6 to 27·5	25·6 to 26·5	24·6 to 25·5	23·6 to 24·5	22·6 to 23·5	21·6 to 22·5	20·6 to 21·5	19·6 to 20·5	18·6 to 19·5	17·6 to 18·5	16·6 to 17·5	15·6 to 16·5
	Frequency																
Kew... ...	68	68	37	22	25	20	11	6	8	1	1	3	1	0	0	0	0
Aberdeen ...	62	39	34	26	17	13	7	8	5	4	2	0	0	0	0	0	0
Edinburgh ...	67	56	48	35	20	21	13	8	4	3	0	1	0	0	0	0	0
Newcastle ...	100	78	49	49	33	18	9	12	9	5	5	2	2	0	0	0	1
Birmingham	87	58	48	50	41	22	20	7	9	4	3	4	3	2	1	0	0
Bristol ...	50	48	39	26	29	20	16	4	7	5	2	2	2	2	1	0	0
Manchester...	68	56	41	34	22	16	8	6	6	6	1	3	0	2	0	0	0

Spells of freezing days.—In order that a study can be made of the cumulative effect of low temperature, spells of freezing days have been investigated. The frequency distributions of spells of not less than three consecutive freezing days are given in Table IX. A spell was not considered terminated by one or more days with temperature exceeding 32·4° F. or 32·5° F. provided that the mean of the temperature of the one or more days and that of the preceding day did not exceed 32·4° F. or 32·5° F. according as spells of T- or T'-freezing days are respectively considered. The table also gives the total number of spells and their average duration.

The average duration of a spell exceeded a week at Edinburgh, Newcastle and Birmingham. The longest spell recorded was one of 47 days at both Edinburgh and Newcastle in 1947.

The cumulative effect of these spells on the temperature of the exterior of buildings will depend upon the mean temperature t of each consecutive day of the spell and the length of the spell. The effect is here expressed in terms of the number of "frost-degree days" which have accumulated each day since the commencement of the spell, the contribution of each day to this number being algebraically equal to $(33-t)$ frost degrees, where t is approximated to the nearest whole degree Fahrenheit.

Table X gives the accumulated number of frost-degree days of such spells of seven or more days at Kew in the 72 winters from the first to the last day of each spell. The mean temperature of each spell is included in this table.

It will be seen from this table that the accumulated number of frost-degree days varies among the spells, and in a spell as its duration increases.

Table XI gives, for the 72 winters at Kew, the total monthly number of spells of one or more T-freezing days and the average and maximum monthly

TABLE IX—TOTAL FREQUENCY OF SPELLS OF THREE OR MORE SUCCESSIVE DAYS WHOSE MEAN TEMPERATURE DOES NOT EXCEED THAT OF A FREEZING DAY

	Type of freezing day	No. of winters	Duration (days) of spell										Average duration of spell	Maximum duration of spell
			3–5	6–8	9–11	12–14	15–17	18–20	21–23	24–26	27–29	>29		
			Frequency										*days*	*days*
Kew	T	72	74	24	8	1	4	2	1	1	0	1	6·1	34
Kew	T'	20	20	9	3	1	2	0	0	0	0	1	6·5	32
Aberdeen	T'	20	21	6	2	0	1	0	0	0	1	0	5·6	28
Edinburgh	T'	20	15	10	4	0	1	0	0	0	0	1	7·3	47
Newcastle	T'	20	16	12	8	4	0	0	0	0	0	1	7·9	47
Birmingham	T'	20	18	11	5	3	2	0	0	1	0	1	7·5	45
Bristol	T'	20	17	8	5	1	1	0	1	0	0	0	6·8	32
Manchester	T'	20	18	7	4	0	0	0	0	1	0	1	7·0	33

TABLE X—ACCUMULATED NUMBER OF FROST-DEGREE DAYS IN SPELLS OF SEVEN OR MORE FREEZING DAYS AT KEW

A spell is not considered terminated by one or more days with temperature exceeding 32·4° F. if the mean of the temperature of the one or more days and that of the preceding day does not exceed 32·4°F.

Period: 72 winters, 1878–79 to 1949–50

	Day of spell																																		
Date of spell	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Average daily tempera-ture of spell
	Accumulated number of frost-degree days																																		°F.
9.12.78 –25.12.78	2	7	9	14	20	26	28	30	35	34	33	36	39	42	52	64	69	...	......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28·9
5.1.79 –12.1.79	2	7	9	11	13	20	28	33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28.9
30.11.79–11.12.79	3	6	15	23	29	34	38	48	47	50	50	58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28·2
12.1.81 –26.1.81	4	11	24	39	51	63	72	83	93	103	109	118	126	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	24·6
10.3.86 –17.3.86	1	2	3	4	4	4	6	7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	32·1
30.12.86–6.1.87	1	7	20	30	27	29	28	29	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29·4
13.3.87 –19.3.87	2	3	4	5	7	8	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31·6
22.2.88 –1.3.88	2	6	11	14	16	16	17	19	22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30·6
13.12.88–6.1.89	5	10	12	15	21	29	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28·1
10.12.90–12.1.91	3	6	11	21	34	40	45	48	52	57	64	63	79	84	88	97	99	100	102	106	114	118	117	123	126	124	125	131	136	140	146	159	171	173	27·9
17.12.91–25.12.91	1	2	6	13	23	34	41	51	56	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	26·8
8.1.92 –16.1.92	2	7	11	11	14	13	14	17	19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30·9
7.3.92 –13.3.92	1	4	8	10	11	12	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31·1
24.12.92–7.1.93	3	7	12	21	27	34	41	44	50	59	66	80	92	95	97	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	26·5
26.1.95 –18.2.95	4	10	15	21	26	31	36	38	41	42	50	64	79	92	107	115	121	128	137	145	149	151	158	161	...	...	...	...	...	...	...	...	...	...	26·3
11.12.99–17.12.99	2	1	3	9	15	15	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30·6
7.2.00 –13.2.00	4	9	17	21	21	25	27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29·1
10.2.02 –17.2.02	2	4	7	11	14	16	23	26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29·7
23.1.17 –9.2.17	1	3	6	10	13	16	20	24	24	25	30	34	37	41	44	52	60	63	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29·5
11.2.29 –19.2.29	6	16	28	40	52	58	62	68	71	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	25·1
18.12.38–25.12.38	5	12	21	27	28	30	30	31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29·1
28.12.39–3.1.40	3	7	11	12	14	17	19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30·3
10.1.40 –24.1.40	1	3	3	7	11	15	19	28	34	37	48	56	57	61	65	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28·7
9.2.40 –18.2.40	1	4	6	12	15	19	21	21	23	25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30·5
11.1.42 –22.1.42	5	8	6	8	14	13	16	18	20	27	36	46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29·2
16.2.42 –22.2.42	1	3	5	6	10	16	19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30·3
20.1.45 –29.1.45	1	3	4	6	12	20	29	36	38	43	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28·7
23.1.47 –1.2.47	1	4	7	11	15	22	34	41	43	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28·6
5.2.47 –25.2.47	2	6	9	11	12	10	14	20	24	26	28	33	39	44	48	52	57	63	70	78	84	...	...	...	...	...	...	...	...	...	...	...	...	...	29·0
1.3.47 –7.3.47	3	4	6	6	6	8	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31·4

duration of these spells when the mean temperature of a *T*-freezing day was less than specified values.

Days with mean temperature exceeding 32·4° F. have not been included. When a spell of freezing days was shared between two months unequally, then the spell was assigned to that month which had the greater number of days; when equally, then the spell was allotted to that month which was closer to January than the other month.

While these spells were most frequent in January their average and maximum durations were greatest in February.

TABLE XI—FREQUENCY AT KEW OF SPELLS OF ONE OR MORE CONSECUTIVE *T*-FREEZING DAYS WITH MEAN TEMPERATURE BELOW SPECIFIED VALUES

Period: 72 winters, 1878–79 to 1949–50

(a) Winter and monthly frequency of spells.
(b) Average winter and monthly duration (days) of these spells.
(c) Maximum winter and monthly duration (days) of these spells.

Mean temperature below °F.		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Winter
32·5	a	23	83	111	68	27	1	313 spells
	b	1·7	2·8	2·8	3·3	3·0	1·0	2·8 days
	c	5	15	12	24	7	1	24 days
30·5	a	11	57	83	45	18	0	214 spells
	b	1·7	2·4	2·2	2·7	1·5	...	2·3 days
	c	4	14	11	11	3	0	14 days
28·5	a	5	34	45	27	4	0	115 spells
	b	1·2	2·2	2·1	2·3	1·7	...	2·1 days
	c	2	6	5	10	3	0	10 days
26·5	a	3	23	26	8	2	0	62 spells
	b	1·0	1·7	1·9	2·7	1·0	...	1·9 days
	c	1	5	5	6	1	0	6 days
24·5	a	1	14	14	3	0	0	32 spells
	b	1·0	1·4	1·9	3·0	...	...	1·8 days
	c	1	2	4	4	0	0	4 days
22·5	a	0	6	8	2	0	0	16 spells
	b	...	1·2	1·6	3·5	...	...	1·7 days
	c	0	2	4	4	0	0	4 days
20·5	a	0	3	4	1	0	0	8 spells
	b	...	1·0	1·3	4·0	...	...	1·5 days
	c	0	1	2	4	0	0	4 days
18·5	a	0	1	2	2	0	0	5 spells
	b	...	1·0	1·0	1·0	...	...	1·0 days
	c	0	1	1	1	0	0	1 day

Table XII gives for the 20 winters the frequency of spells of one or more consecutive *T′*-freezing days with mean temperature below specified values. Here, days with mean temperature exceeding 32·5° F. have been omitted. The total number of spells, their average duration and the duration and month of occurrence of the longest spell are included in the table.

From this table the average duration of spells of two or more consecutive days can be evaluated. The table shows that the average duration of spells of freezing days below 32·6° F. and 30·6° F. is greatest at Bristol and Newcastle.

TABLE XII—FREQUENCY OF SPELLS OF ONE OR MORE CONSECUTIVE T'-FREEZING DAYS WITH MEAN TEMPERATURE BELOW SPECIFIED VALUES

Period: 20 winters, 1927–28 to 1946–47

Temp. below	Duration of spells (consecutive days) 1	2	3	4	5	6	7	8	9, 10	11, 12	13, 14	15, 16	17, 18	19, 20	>20	Total No. of spells	Average duration of spells	Longest spell Duration	Longest spell Month of occurrence
°F.	Frequency																days	days	
KEW																			
32·6	43	17	8	7	3	3	4	2	3	2	0	1	0	0	0	93	2·9	15	Feb.
30·6	33	11	6	3	2	1	0	0	3	1	0	0	0	0	0	60	2·3	11	Feb.
28·6	16	7	4	5	1	2	0	0	0	0	0	0	0	0	0	35	2·3	6	Feb.
26·6	4	4	6	1	0	0	0	0	0	0	0	0	0	0	0	15	2·3	4	Jan., Feb.
24·6	7	3	0	1	0	0	0	0	0	0	0	0	0	0	0	11	1·5	4	Jan.
22·6	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	1·5	3	Feb.
20·6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.0	1	Feb.
ABERDEEN																			
32·6	44	17	10	8	3	1	2	1	1	1	1	0	0	0	0	89	2·4	13	Mar.
30·6	22	14	4	1	2	0	0	1	1	1	0	0	0	0	0	46	2·3	12	Mar.
28·6	17	5	2	1	3	0	0	0	0	0	0	0	0	0	0	28	1·9	5	Jan., Mar.
26·6	11	4	1	0	0	0	0	0	0	0	0	0	0	0	0	16	1·4	3	Mar.
24·6	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1·1	2	Jan.
22·6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1·0	1	Jan.
EDINBURGH																			
32·6	46	20	6	7	6	3	1	2	1	0	0	1	0	0	1	94	2·9	47	Feb.
30·6	23	10	7	4	3	1	1	0	2	1	1	0	0	0	0	53	2·8	13	Feb.
28·6	17	8	5	4	1	0	0	0	0	0	0	0	0	0	0	35	2·0	5	Jan.
26·6	11	2	3	1	0	0	0	0	0	0	0	0	0	0	0	17	1·6	4	Jan.
24·6	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	1·4	3	Feb.
22·6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1·0	1	Feb.
NEWCASTLE																			
32·6	51	22	12	10	3	8	3	4	2	2	0	0	0	0	1	118	3·1	42	Feb.
30·6	36	14	12	4	5	3	2	1	1	0	0	0	0	0	0	78	2·4	9	Jan.
28·6	26	9	2	3	0	4	0	1	0	0	0	0	0	0	0	45	2·1	8	Jan.
26·6	16	2	3	1	1	1	0	0	0	0	0	0	0	0	0	24	1·8	6	Feb.
24·6	12	1	1	0	0	1	0	0	0	0	0	0	0	0	0	15	1·5	6	Feb.
22·6	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1·1	2	Feb.
20·6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1·0	1	Jan., Feb.
18·6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1·0	1	Feb.
16·6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1·0	1	Feb.
BIRMINGHAM																			
32·6	65	35	10	6	4	2	3	3	5	2	0	0	0	0	1	136	2·6	22	Feb.
30·6	40	15	6	4	5	2	2	3	2	0	0	1	0	0	0	80	2·4	15	Feb.
28·6	24	6	6	6	1	0	3	0	1	0	0	0	0	0	0	47	2·4	10	Feb.
26·6	13	5	5	1	1	1	0	0	0	0	0	0	0	0	0	26	2·0	6	Feb.
24·6	7	3	1	1	1	0	0	0	0	0	0	0	0	0	0	13	1·9	5	Feb.
22·6	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	6	2·2	4	Feb.
20·6	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	1·5	3	Feb.
18·6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1·0	1	Feb.
BRISTOL																			
32·6	32	8	12	4	2	3	2	2	5	1	0	1	0	0	1	73	3·5	22	Feb.
30·6	19	12	7	7	1	3	0	0	1	0	0	2	0	0	0	52	3·0	16	Feb.
28·6	12	5	6	4	1	2	0	2	0	0	0	0	0	0	0	32	2·8	8	Jan.
26·6	9	3	4	0	1	0	1	0	0	0	0	0	0	0	0	18	2·2	7	Feb.
24·6	5	1	3	1	0	0	0	0	0	0	0	0	0	0	0	10	2·0	4	Feb.
22·6	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	6	1·5	3	Feb.
20·6	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	1·7	3	Feb.
18·6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1·0	1	Feb.
MANCHESTER																			
32·6	46	21	5	6	8	4	2	2	2	0	1	1	0	0	0	98	2·7	15	Feb.
30·6	22	29	4	8	1	1	1	0	2	0	0	0	0	0	0	68	2·1	9	Jan., Feb.
28·6	18	15	1	1	0	1	1	0	0	0	0	0	0	0	0	37	1·8	7	Jan.
26·6	9	3	2	0	2	0	0	0	0	0	0	0	0	0	0	16	1·9	5	Jan., Feb.
24·6	6	3	1	1	0	0	0	0	0	0	0	0	0	0	0	11	1·7	4	Jan.
22·6	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	2·0	3	Jan.
20·6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1·0	1	Jan.

Air masses associated with freezing days.—An examination has been made of the air masses associated with *T*-freezing days at Kew and Aberdeen during the 20 winters 1927–28 to 1946–47, the total number of freezing days at these stations being respectively 242 and 180. When, as frequently occurred, more than one air mass covered the station during the day (0h.–24h.) that air mass was selected which persisted over the station for the greatest number of hours. The air masses were found to be confined to (*a*) direct polar air moving

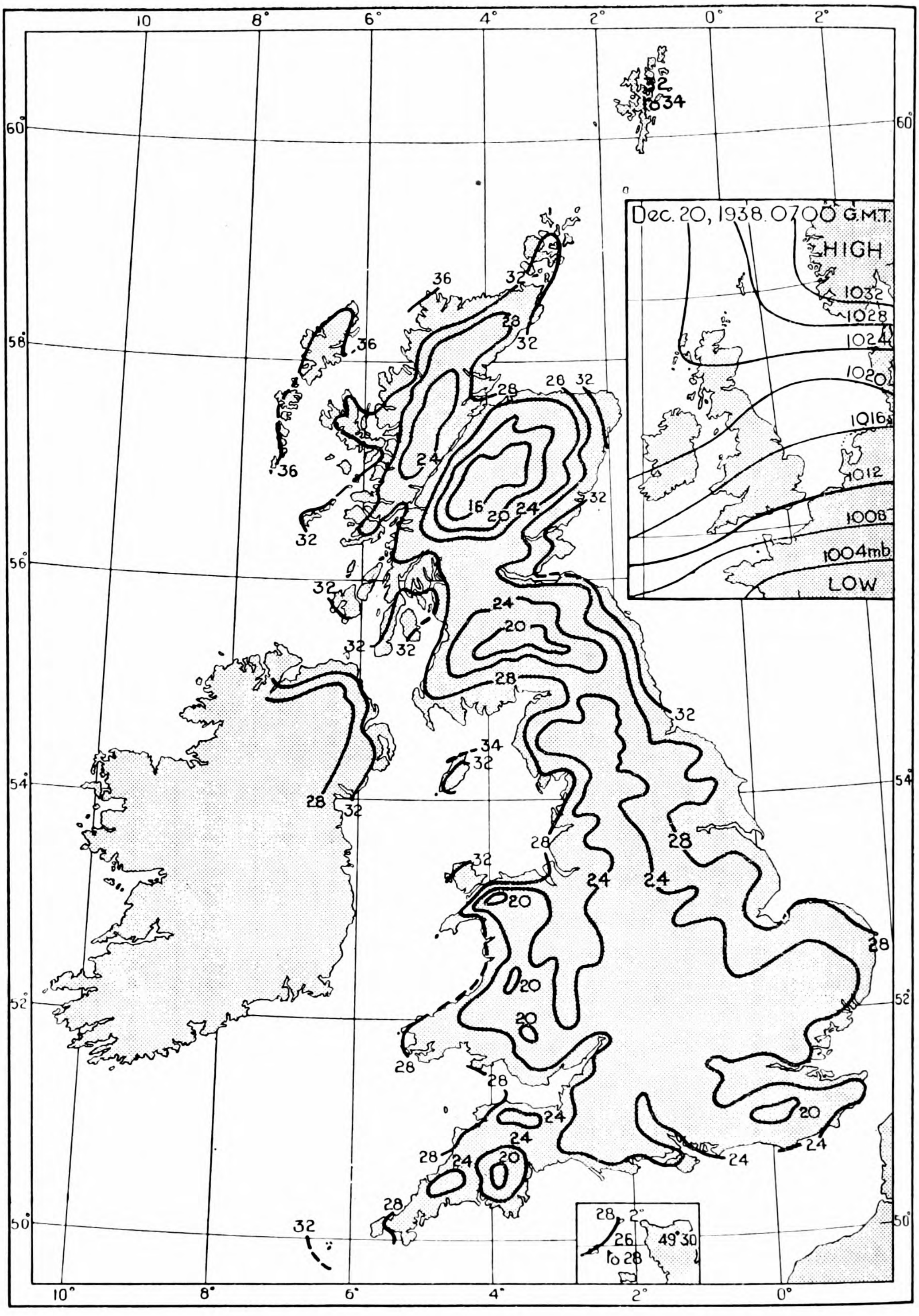

10
8°
6°
4°
2°
0°
2°
60°
58°
56°
54°
52°
50°
Dec. 20, 1938. 0700 G.M.T.
HIGH
1032
1028
1024
1020
1016
1012
1008
1004mb.
LOW
36
32
28
24
20
16
34
26
49°30
to 28

FIG. I—MEAN TEMPERATURE IN DEGREES FAHRENHEIT IN POLAR CONTINENTAL (SIBERIAN) AIR

December 20, 1938

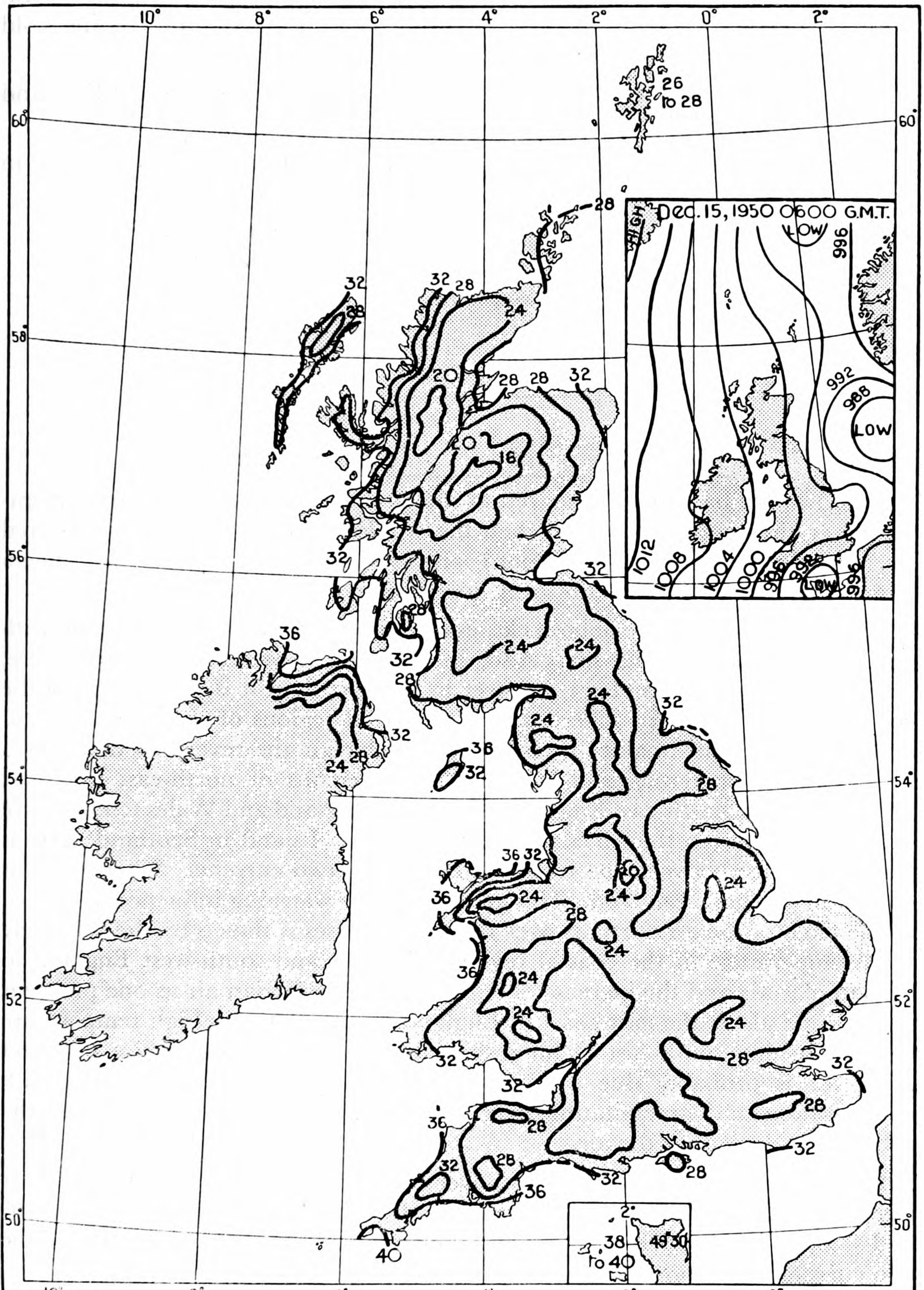

10°
8°
6°
4°
2°
0°
2°
60°
58°
56°
54°
52°
50°
26 to 28
28
32
28
32 28
24
20
28 28 32
20
16
32
32
24
24
36
32
28
32
24 28
38
32
24
32
28
36 32
36
24
28
24
24
36
24
24
24
28
32
32
32
28
36
28
32
28
32
28
36
32
40
38 to 40
45 30
Dec. 15, 1950 0600 G.M.T.
HIGH
LOW
996
992
988
LOW
1012
1008
1004
1000
996
996
LOW
996

FIG. 2—MEAN TEMPERATURE IN DEGREES FAHRENHEIT IN DIRECT POLAR AIR
December 15, 1950

southwards over the country from beyond latitude 70° N., (*b*) polar continental air, including Siberian air, moving westwards from north-east, east and central Europe, and (*c*) polar air in and near the central regions of moving cold anticyclones.

The percentage frequencies of these air masses on *T*-freezing days at Kew and Aberdeen are given in Table XIII.

The table shows that more than half the number of freezing days occurred in direct polar air at Aberdeen and in polar continental air at Kew.

TABLE XIII—PERCENTAGE FREQUENCY OF DIFFERENT CLASSES OF AIR ASSOCIATED WITH *T*-FREEZING DAYS

Period : 20 winters 1927–28 to 1946–47

	Class of air		
	Direct polar	Polar continental	Anticyclonic
	Percentage frequency		
Kew	14·5	50·4	35·1
Aberdeen	51·6	25·6	22·8

Figs. 1 and 2 have been prepared to show the distribution of mean temperature over the country on days when the whole of Great Britain was covered by (*a*) polar continental (Siberian) air, (*b*) direct polar air. The mean temperature at station level of over 300 stations has been used.

The mean temperature of both classes of air decreases with elevation and with distance inland from the sea. Also, in both air masses mean temperature, except in north-west England, is lower in the east than it is in the west of the country, but whereas in Siberian air the coastal regions of southern England and Wales are much colder than in direct polar air the reverse is the case in Orkneys and Shetlands and in the coastal regions of north-east and east Scotland and of north-east England. Inland in England and Wales temperature is lower in Siberian than it is in direct polar air. Inland in Scotland there is little difference between the temperatures of the two currents. Siberian air is coldest in southern England. The increase in the warming influence of the sea as the fetch of the air currents over the sea increases is shown by the relatively high temperature in the coastal regions of Wales and south-west England in direct polar air and the increase of temperature in Siberian air as one proceeds northwards along the east coast of England. The relatively high temperature over Flintshire, south-east Denbighshire and north-west Shropshire in direct polar air is probably due to the forced ascent of this air associated with condensation and precipitation over the mountains of north Wales and the subsequent descent of the air.

In the mornings the temperatures over East Anglia in Siberian and polar air were respectively 10° F. and 18° F. at 4,000 ft., −7° F. and −3° F. at 10,000 ft. and −25°F. and −22°F. at 15,000 ft. The temperature difference between the two currents therefore decreased with increasing height.

ERRATA

April 1951, PAGE 105, caption to the diagram; *for* " JANUARY 16, 1946 " *read* " JANUARY 12, 1946 ".

May 1951, PAGE 127, key within the diagram; *for* " maximum " read "minimum ", *for* " minimum " *read* " maximum ".

EFFECT OF HEAVY RAIN ON PILOT BALLOONS

Experiments on the effect of rain on the rate of ascent of pilot balloons have recently been made at the meteorological office, Shoeburyness.

The first part of the following report describes the observations made by Messrs. J. Chester, F. A. Landon and L. A. Ibberson during an experiment on May 24, 1951, and the second part by Mr. E. Knighting considers and rejects a suggestion that the balloon was leaking and describes the result of a trial of the release of a wetted balloon from a point 65 ft. up a tower.

Part I—Pilot-balloon ascent in heavy rain

On Thursday, May 24, 1951, very heavy rain followed a thunderstorm which was accompanied by sudden shifts of wind (090°–190°–150°) and a sudden rise in pressure. We decided to make a double-theodolite pilot-balloon ascent in the heavy rain with the object of determining the effect of heavy rain on the rate of ascent of the balloon.

At 0815 G.M.T., when the balloon was launched, there were 5 oktas cumulonimbus, base 1,800 ft., 2 oktas fractostratus, base 800 ft., and 8 oktas nimbostratus, base 6,500 ft.; the surface wind was calm and the visibility in the heavy rain 2,000–3,000 yd. For the first 2 min. of the ascent the rain was heavy; from 2 min. to 4½ min. the rain was very heavy and subsequently the rain became heavy again. In the first 3 min. the balloon rose to about 800 ft., after which it descended and reached the surface of the sea, where it bounced a few times before settling down on the water and drifting out of sight.

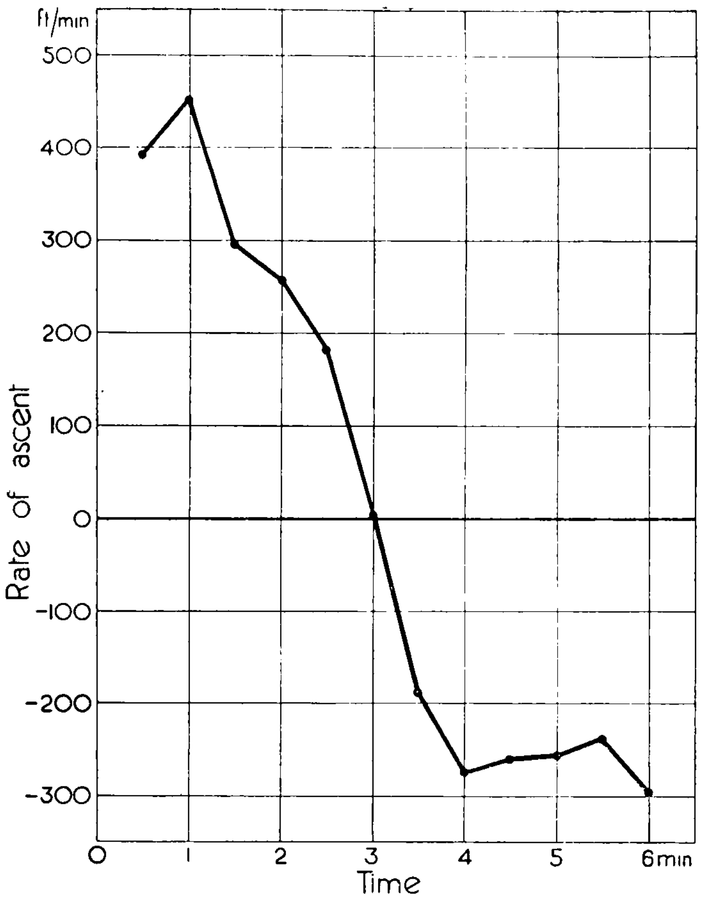
Some extracts from the data are given in the following table:—

DOUBLE-THEODOLITE PILOT-BALLOON ASCENT

Date: May 24, 1951.
Time of start: 0815 G.M.T.
Length of base line: 530 ft.
Free lift of 48-in. balloon: 20 gm.
Nominal rate of ascent: 400 ft./min.
Calculated rate of ascent: 395 ft./min.

Time from start	Wind velocity Direction	Wind velocity Speed	Mean height	Rate of ascent
min.	° true	ft./sec.	ft.	ft./min.
½	102	3	196	392
1	270	1	422	452
1½	247	7	470(570)	96(296)
2	275	15	699	458(258)
2½	270	25	790	182
3	276	19	792	4
3½	276	19	698	−188
4	279	13	561	−274
4½	293	9	431	−260
5	315	8	313	−256
5½	339	6	194	−238
6	015	4	46	−296
6½	350	6	−38	

The readings were difficult to make owing to the heavy rain and we regard the height at 1½ min. as suspect since it is the only reading in which the average height varied by more than about 20 ft. from the individual heights. We have therefore inserted in brackets a reasonable value as given by one of the stations. The resulting rates of ascent are plotted against time in the accompanying diagram.



RATE OF ASCENT OF BALLOON IN HEAVY RAIN

The diagram shows three periods, (*a*) an initial period when there was little or no water on the balloon and the balloon rose at approximately the nominal rate, (*b*) a period in which the rate of ascent declined steadily and water collected on the balloon, (*c*) a period when the rate of descent was steady and no more water was able to collect on the balloon. The second of these periods coincided approximately with the period of very heavy rain. Other factors which may have influenced the downward motion are the downward impact of the rain and possibly a down-draught in the cumulonimbus cloud.

Part II

The balloon referred to in Part I did not behave as leaky balloons do, though as it was lost on the sea certainty is impossible. An inflated balloon which is punctured bursts and the fabric is torn with consequent rapid deflation which certainly did not occur. A balloon punctured before inflation hisses as gas escapes on inflation and cannot usually be blown to full pressure without tearing the fabric. The appearance of the balloon, according to the observers, did not suggest deflation. A 48-in. balloon in equilibrium with its surroundings has a diameter of 32 in. so that a balloon descending for lack of gas presents a surface less than one half of a fully inflated balloon. No diminution in size was apparent but the argument is not strong as it is probably difficult to detect a gradual diminution. It is doubtful if it would have bounced on the sea surface after 3½ min. deflation as an under-inflated 48-in. balloon is flabby.

A trial was made by taking a 48-in. balloon, fully inflated, to near the top of the Conning Tower where it was thoroughly soaked in water and released. On release it fell vertically to the ground and was recaptured. After drying, the free lift was 17 gm. compared with 20 gm. before wetting; it may be that the balloon fabric retains water. The same balloon was re-wetted and released near the ground when it fell and scurried along the ground before slowly rising as the water evaporated and free lift was restored.

This experiment leads to the belief that the descent of the balloon released in heavy rain was produced by deposition of water and not by loss of hydrogen.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society on June 20, 1951, with Sir Robert Watson-Watt, President, in the Chair, Officers for the coming year were formally elected. The new President for 1951–53 will be Sir Charles Normand. The following papers were then read:—

Smith, E. J.—Observations of rain from non-freezing clouds[*]

Since the whole of the work covered by this paper had been described by Dr. Bowen to the Society on April 18[†] at the suggestion of the President the paper was taken as read.

Best, A. C.—The size of cloud droplets [‡]

In this paper Mr. Best set out to show why cloud droplets should have diameters within the range 5–40μ. He started from Wright's equation for the vapour pressure over a drop of salt solution leading to a likely maximum value of supersaturation of about 0·05 per cent. He then showed how it was possible to calculate the rate of growth of a drop by condensation, and therefore how large the drop would be before it left the cloud by turbulent diffusion or by falling out under the influence of gravity. The calculated drop radius before being carried out of the cloud by diffusion was in reasonable accord with published measurements of the mean drop radius, and the droplet falling out of the cloud under gravity was of the same order as the largest cloud-drop measurements. At higher temperatures the drop would grow more quickly and would therefore be bigger before it fell out in a shorter time.

Ludlam, F. H.—The production of showers by the coalescence of cloud droplets

Mr. Ludlam gave an entertaining lecture on his paper which was an effort to define the conditions under which showers may develop from convective cloud by the coalescence mechanism. He admitted to making many assumptions but he thought the results were approximately true. Growth by condensation alone was insufficient to produce droplets larger than 110μ in less than a day; a cumulus cloud often only lasted 20 min., and for a shower real drops had to be produced in about 10 min. Since a raindrop was equivalent to as many as a million cloud droplets the coalescence mechanism required relatively few drops to start growing, and it was therefore legitimate to consider only the growth of the largest drops.

Even with giant nuclei a small droplet could only increase by about 2μ in diameter by condensation during 20 min. But evaporation was also slow so that droplets starting as sea spray would have diameters of 20 or 30μ in a cloud, and he had calculated the growth of such drops.

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[*] *Quart. J.R. met. Soc., London*, **77**, 1951, p. 33. [‡] *Quart. J.R. met. Soc., London*, **77**, 1951, p. 241.
[†] *Met. Mag., London*, **80**, 1951, p. 194.

From Langmuir's formulæ for the efficiency of catch of small droplets it was possible to calculate the rate of growth of the droplets under given conditions of up-draught, initial drop diameter and temperature at the base of the cloud, and therefore the necessary conditions for a shower by the coalescence mechanism. Mr. Ludlam had modified Langmuir's formulæ slightly to allow for the small difference in diameter between the two drops which coalesce. With this modification the efficiency of collection varied between 75 and 100 per cent. when the height above the cloud base exceeded 600 m. Mr. Ludlam showed several diagrams, some illustrating the relation between initial drop size, up-draught and final drop size; some, the decrease in size of drop falling through air of 90 per cent. relative humidity; and some, the variation of minimum cloud depth for shower development as a function of up-draught and initial drop size and also as a function of temperature at the cloud base. The minimum condition for showers is given as the production of drops exceeding 150μ in radius, and the consequent variation of cloud depth is from 1,400 m. at cloud-base temperature of 20°C. to 1,800 m. at cloud-base temperature of $-5°$ C.

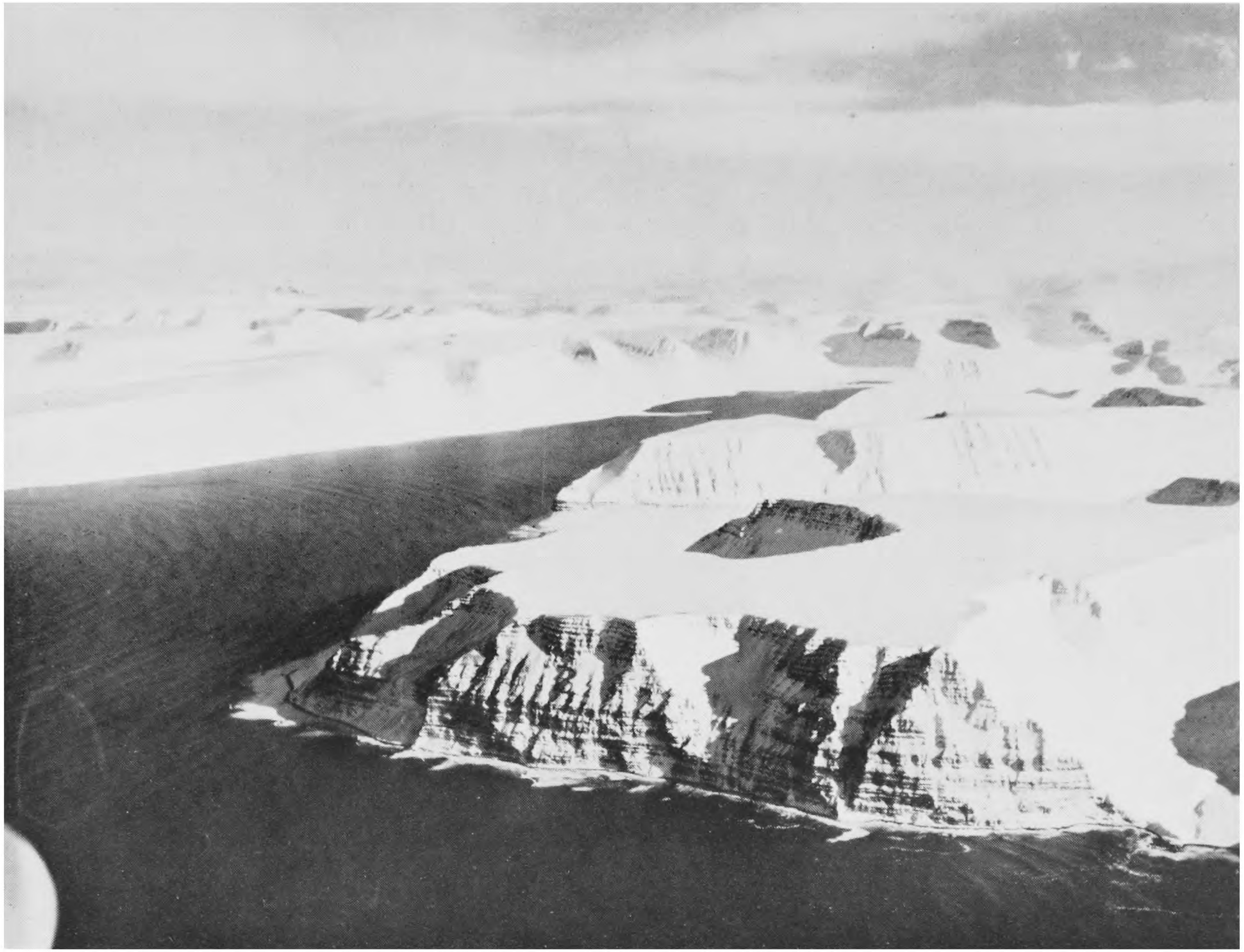
As a further corollary to his theory Mr. Ludlam also suggested that raindrop breaking could only occur with cloud depth greater than certain given heights and only if the raindrop did not pass through the ice phase. In support of this statement he showed a map of " sferic " activity over the northern North Atlantic during November and December 1949. The activity, except for a distant area of low accuracy of observation, was confined to the south of the 43° F. sea-temperature isotherm which corresponds to a cloud-base temperature at 2,000 ft. of 0° C.

In the discussion on these three papers Mr. Mason thought Mr. Best had assumed his answer to start with in the calculation of the excess vapour pressure. Mr. Gold questioned the application by Mr. Best of O. G. Sutton's dispersion formula to the turbulent transfer of a droplet out of the cloud since turbulence depends on wind shear not wind speed. He thought Mr. Ludlam should have considered the cloud-droplet size more carefully, for there was a tendency for drops to be of uniform size which would produce a separation of the different sizes into layers. Mr. Woodcock queried Mr. Ludlam's modification of Langmuir's collection coefficient from approximately $\frac{1}{4}$ to nearly $\frac{3}{4}$ or 1.

*Scorer, R. S.—Billow clouds**

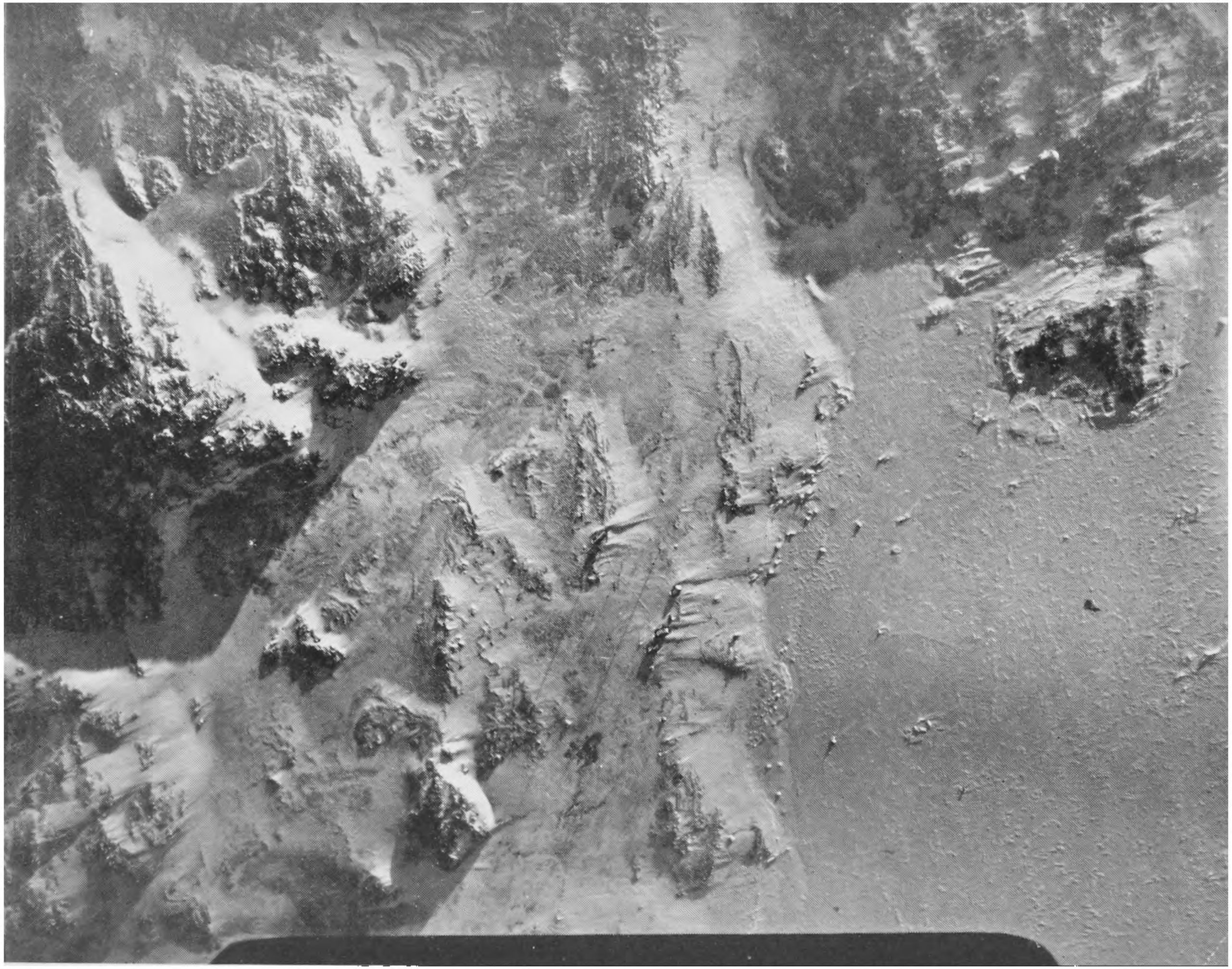
Dr. Scorer pointed out some difficulties in the generally accepted theory of the formation of billow clouds as convection cells whose configuration is influenced by shearing motion at the almost horizontal boundary between two air currents. Although laboratory experiments had reproduced many of the patterns, conditions had to be exactly right. This fitted in with Jeffreys' further assumption that the motion will only just take place in order to obtain the cell size. The conditions are not usually exactly right in the atmosphere; and furthermore a convection cell is a mechanism for the continuous transport of heat—which was not likely to take place at a transition boundary.

**Quart. J.R. met. Soc., London,* 77, 1951, p. 235.



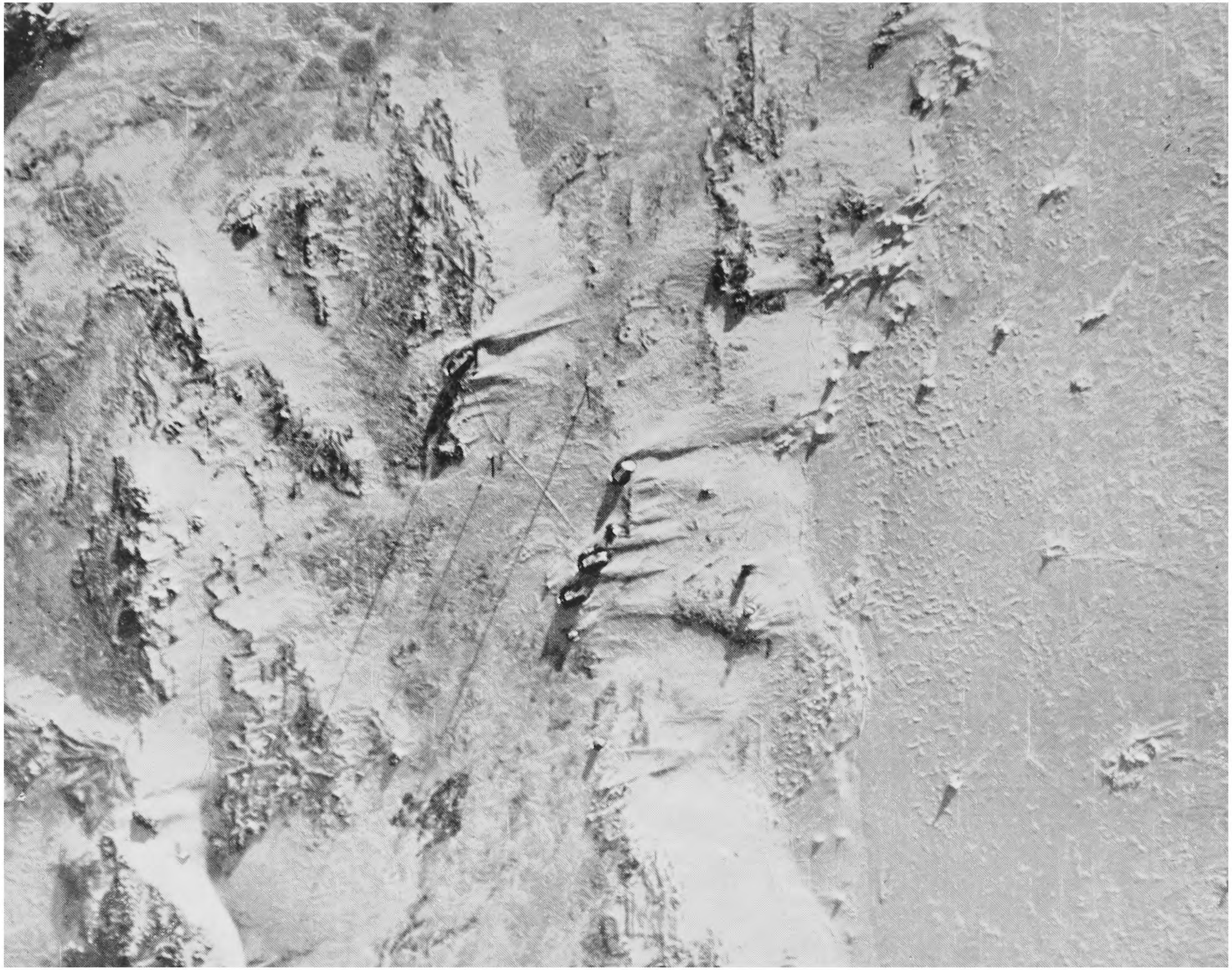
Photograph by R.A.F.

FIG. 1—ONUNDARFJORDUR NEAR BOLUNGARVIK, NORTH-WEST ICELAND (see p. 233)



Photograph by R.A.F.

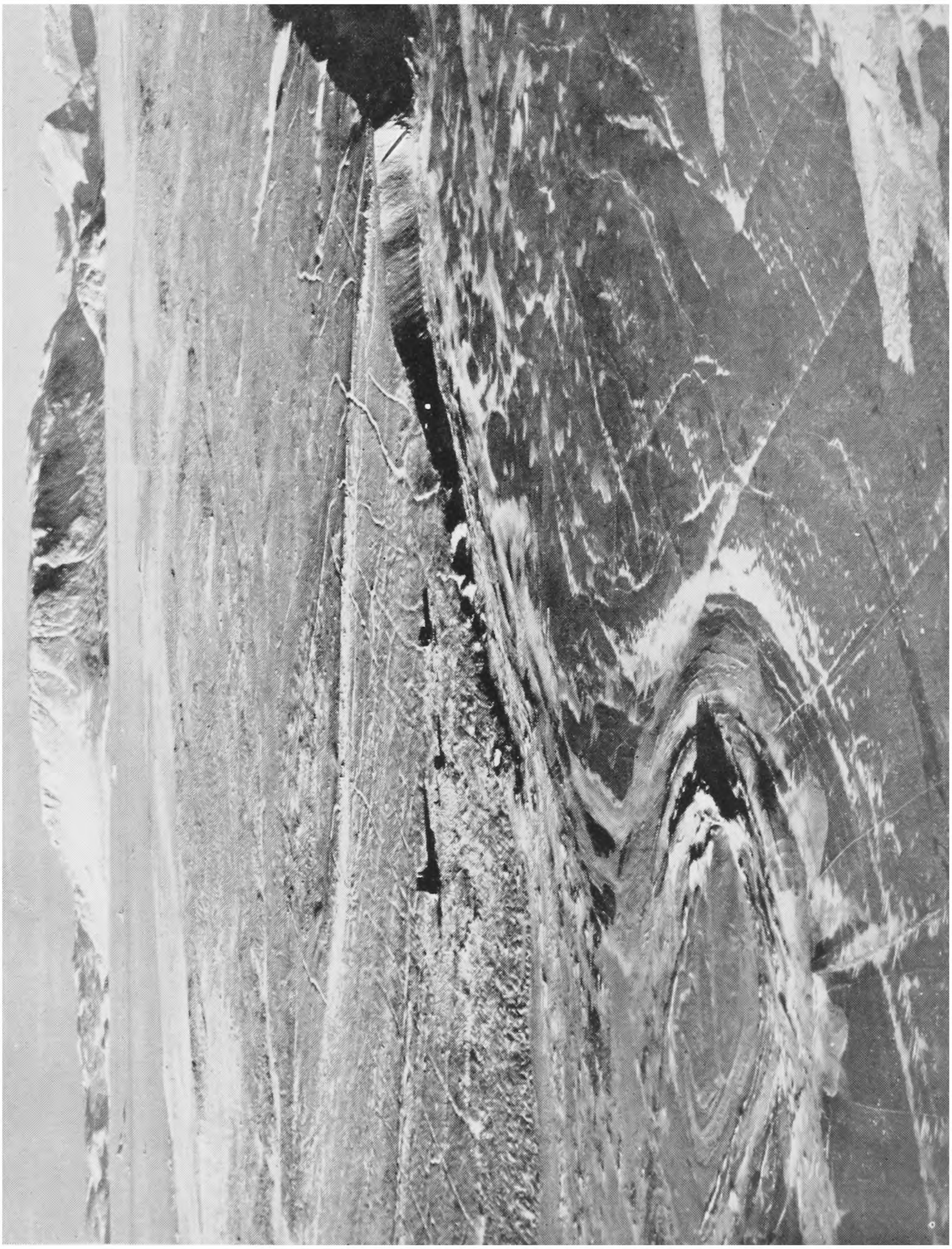
FIG. 2—AREA AROUND DANMARKSHAVN, NORTH-EAST GREENLAND



Photograph by R.A.F.

FIG. 3—SYNOPTIC REPORTING STATION DANMARKSHAVN

To face p. 229]



Photograph by R.A.F.

FIG. 4—TRAPPER'S ENCAMPMENT AT HUALROSODDEN NEAR DANMARKSHAVN

The theory suggested by Helmholtz of waves at a surface of discontinuity did not explain the appearance of a single wave-length, and although Wegener had obtained a single wave-length this was by arbitrarily assuming that the waves travelled with a velocity equal to the mean of those above and below the discontinuity. Alternatively one could assume that there was a layer of unstable air, but then vertical overturning occurs and the problem is again one of convection.

Dr. Scorer therefore produced the theory that there was a row of parallel vortices at the level where stable waves existed between the wind currents. This led to a formula, wave-length$=2{\cdot}6938h$, where h is the depth of the statically unstable layer. He showed photographs, from the Clarke Collection, illustrating billow clouds which he thought had been derived according to his theory.

In the short discussion which followed Dr. Sutcliffe wished more distinction had been made between cloudlets that were distinct in themselves and cloud forms such as lenticular clouds which remained more or less stationary with cloudlets passing through them. Mr. Ludlam drew attention to the well known danger of taking nephoscope observations on wave clouds.

LETTERS TO THE EDITOR

High-level cloud photographs

We should like to make a few comments on the notes given by G. W. Hurst on his Figs. 4 and 5 in the March 1951 issue of the *Meteorological Magazine.*

The " fault " shown in Fig. 4 is quite different from the one described by Frith in *Nature**. The latter was straight and the cloud top on each side was at the same level. It appeared that the " fault " might have been a V-shaped trough in the cloud top. In the former, on the other hand, the height of the cloud top is clearly different on each side of the "fault".

Investigations of the temperature structure of cloudless inversions carried out by the Meteorological Research Flight using a thermometer with a very rapid response have shown that the increase in temperature with height is often confined to a layer less than 100 ft. thick, and that the height of this layer appears on occasions to change abruptly. It is possible that Mr. Hurst's Fig. 4 shows a cloud structure associated with such a discontinuity.

Mr. Hurst explains the bright spot in Fig. 5 as reflection of the sun from a lake or river surface. It seems to us, however, that it is a good example of a sun image produced by reflection of the sun from the flat surfaces of ice crystals. Although it does not appear to be in the cloud, there are always many ice crystals around and below the type of cloud shown in Fig. 5 which would produce the image. These might not show up clearly on a photograph, and, in fact, might not even be visible from the aircraft. A sun image apparently clear of cloud is a very common feature and its presence is often the only evidence for the existence of ice crystals.

D. R. GRANT
RONALD FRITH
H. C. SHELLARD

June 6, 1951

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*FRITH, R.; Details of wind structure revealed by artificial nucleation of supercooled clouds. *Nature, London,* **165**, 1950, p. 899.

Precautions to prevent sea-gulls stealing sunshine cards

I have had considerable previous trouble with sea-gulls attacking the sunshine recorder, notably during the winter of 1949–50 during reconstruction of its usual site when I used a neighbouring roof.

I found cutting off the ends of the cards fairly effective but it makes them very difficult to get out. The recorder used to have clamping screws but they have corroded away. A pin through the hole serves quite well.

But I have recently been trying another idea. I argued that the birds stand near the recorder while pulling at the card. I have tried to make this impossible to a web-footed bird by using old pieces of board with 1½ in. panel pins scattered over them points upwards (driven through from the back), so far with success. Rather dangerous to the one in charge of the instrument, too, so I have found!

C. WINDASS

Observatory Office, Torquay, June 27, 1951

NOTES AND NEWS

Napier Shaw Library, Cambridge

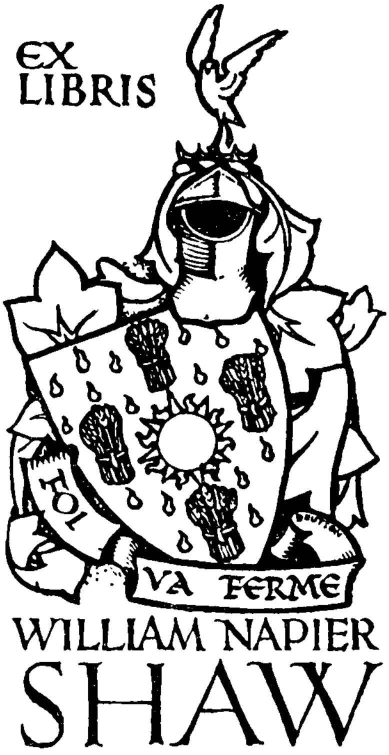
Sir Napier Shaw possessed what was probably the largest private library of meteorological books in the country, and in his will he expressed the wish that " a permanent home within the precincts of the University of Cambridge " be found for it with a view to promoting the future study of the atmosphere. Until recently these books have been in the charge of the Director of the Observatory at Cambridge, but the recent decision to centralize meteorological activity in the Cavendish Laboratory has resulted in the transfer of Shaw's Library as well.

During the afternoon of June 11, 1951, the formal opening of the Napier Shaw Library, which is now housed in one of the rooms of the Cavendish Laboratory, was performed by the Vice-Chancellor of the University, who was supported by the Cavendish Professor and the Mayor of Cambridge. Some 25 distinguished meteorologists from many parts of the country were present. In a brief but felicitous speech the Vice-Chancellor recalled the association of Sir Napier Shaw with the Cavendish Laboratory, and declared the Library open. Speaking on behalf of Sir Napier Shaw's Trustees, Miss Austin expressed appreciation of the steps the University has taken to carry out the wishes of Sir Napier Shaw.

Every meteorologist will wish to echo the sentiments expressed by Miss Austin, and will be glad to know that the great debt we all owe to Sir Napier for his outstanding contribution to the science of meteorology is enhanced by his foresight in thus making his library available to later generations of research workers.

In addition to the books, certain other interesting relics were bequeathed to the University, including a clock, Shaw's Royal Medal, his Symons Memorial Medal, his Buys Ballot Medal, and an imposing document in which the College of Arms granted to Sir Napier Shaw his coat of arms. The clock was one given to Shaw by his colleagues in the Cavendish Laboratory and which thus returns to its place of birth.

Shaw's coat of arms will be of interest to those who are concerned with the help that meteorology can give to agriculture. It consists, in ordinary parlance, of a sky-blue shield on which a radiant sun is placed centrally and surrounded by heraldic raindrops and four sheaves of corn. The crest above the coat of arms depicts a " stormy petrel " in flight over a rough sea. The coat of arms was used by Shaw as a book-plate, and is thus shown below, together with its description in heraldic terminology.



SIR NAPIER SHAW'S COAT OF ARMS
USED AS A BOOK-PLATE

Azure guttes d'eau a Sun in splendour Argent between four Garbs in cross Or
and for the Crest On a Wreath of the Colours:
On waves of the sea a Petrel passant and volant all proper.

Temporary formation of a surface inversion as a consequence of wintry showers

A remarkable example of the cooling of the surface temperature by a wintry shower was seen on the Cumberland coast on February 6, 1951. This cooling led to the formation of an inversion, from the surface to a height above 350 ft., which persisted for 2½–3 hr. The presence of this inversion was made plainly visible by a smoke trail from a factory chimney. It was the unexpected behaviour of this smoke trail that led to a closer examination of the meteorological records. The detailed sequence of weather was as follows:—

A slight shower of rain commenced at 0830 G.M.T., and became a heavy hail shower at 0853 with 8 oktas cumulonimbus, base estimated at 800 ft., and 2 oktas fractocumulus at 600 ft. The shower turned to moderate snow for a short time at 0903 before its cessation. The visibility during the hail shower was 2½ miles. At 0930 another hail shower occurred, and though it was not nearly so intense as the previous one, the visibility fell rapidly to 900 yd. and the cloud base fell to the surface. By 0955 the visibility had improved to 1½ miles and the cloud base to 700 ft., and it was then that the peculiar behaviour of the smoke trail became apparent. A further hail shower occurred at 1045 and a snow shower at 1120, the latter being accompanied by a squall to 33 m.p.h.

The temperatures recorded in the screen during this period were:

	0900	1000	1030	1100	1200
			degrees Fahrenheit		
Dry bulb	37·0	33·2	33·2	33·3	36·2
Wet bulb	35·0	32·8	...	33·0	35·8

The interesting feature about these temperatures is the fall between 0900 and 1000 to a point below the previous wet-bulb temperature. A fall to this latter value would represent the maximum cooling possible as a result of the evaporation of falling rain. The additional cooling below the previous wet-bulb temperature, leading to the fog (cloud) formation, was presumably a result of the precipitation reaching the ground as ice, and probably existed in only quite a shallow layer (see Fig. 1).

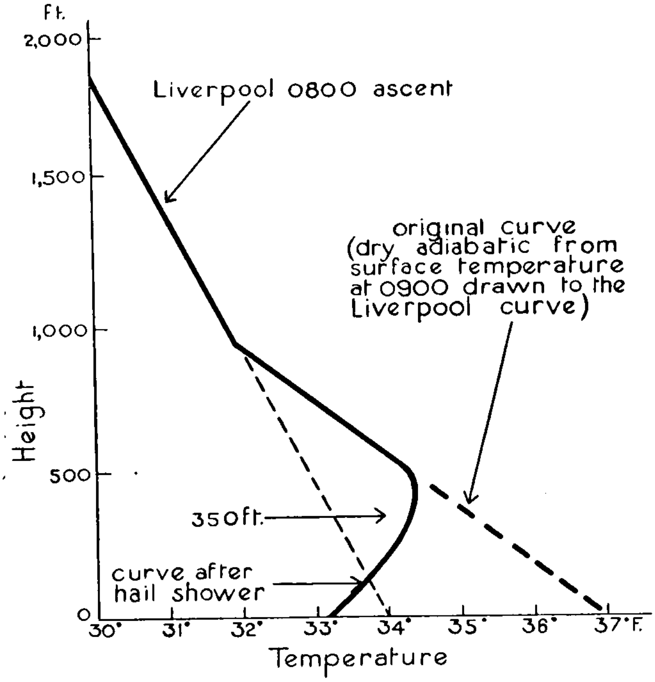


FIG. 1—PROBABLE TEMPERATURE VARIATION WITH HEIGHT BEFORE AND AFTER THE HAIL SHOWER

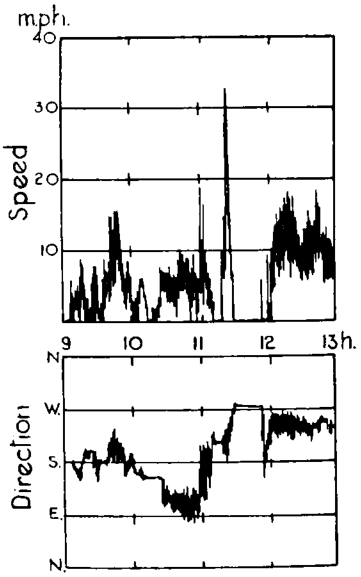


FIG. 2—ANEMOGRAPH TRACE

The anemograph trace for the period (Fig. 2) shows two interesting and contrasting features. These are (i) the almost complete lack of turbulence, shown by the very narrow direction trace between 1005 and 1020, and (ii) the well defined squall from calm to 33 m.p.h. and back to calm at 1122 indicative of the real instability of the air mass, as were also a squall to 20 m.p.h. at 0849 and the subsequent showers.

Fig. 3 is a diagrammatic representation of the smoke trail. This issued from a stack 60 ft. high and formed, for a time, a quite dense and almost stationary cloud over a building 200 ft. high, and some 150 yd. away. The top of another stack 400 ft. above ground, and rising out of the building was plainly visible above the smoke cloud which levelled off at a height of 350 ft. and then descended out of view behind some buildings, but apparently almost to ground level, a short distance further on.

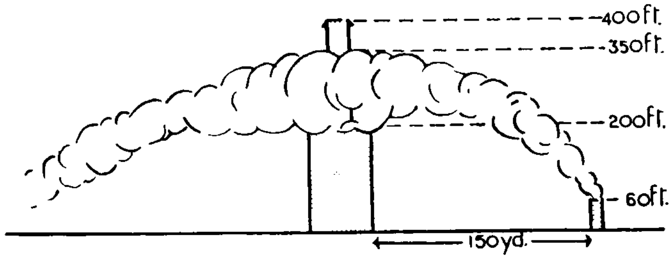


FIG. 3—DIAGRAMMATIC REPRESENTATION OF SMOKE TRAIL

The Liverpool ascent at 0800 showed a lapse of temperature from 34° F. at surface to 32° F. at approximately 1,400 ft., above which the air mass was quite unstable to about 20,000 ft. No 0800 local surface temperature was available, but at 0900 it was 37·0° F., and the minimum temperature for the 24 hours ending at 0900 was 36·7° F.

The appearance of the smoke trail leads to the assumption that an inversion had formed with top above 350 ft. Having regard to the available temperature information and the weather phenomena it is probable that this inversion was very steep near the surface, and Fig. 1 depicts the probable change in temperature with height before and after the first hail shower. The inversion persisted till about 1145 as could be seen by the smoke trail keeping an almost level path at about 350 ft. but in various directions as the wind shifted. The shape of the smoke trail can be explained on the supposition that the smoke was warmer than the surrounding air at the top of the chimney, and that its initial uplift was sufficient to carry it up through the inversion to 350 ft. and no further, as it descended again from that level. Further supporting evidence of the existence of the inversion is shown on the anemograph trace by the effect on the surface wind when it broke down just before 1200.

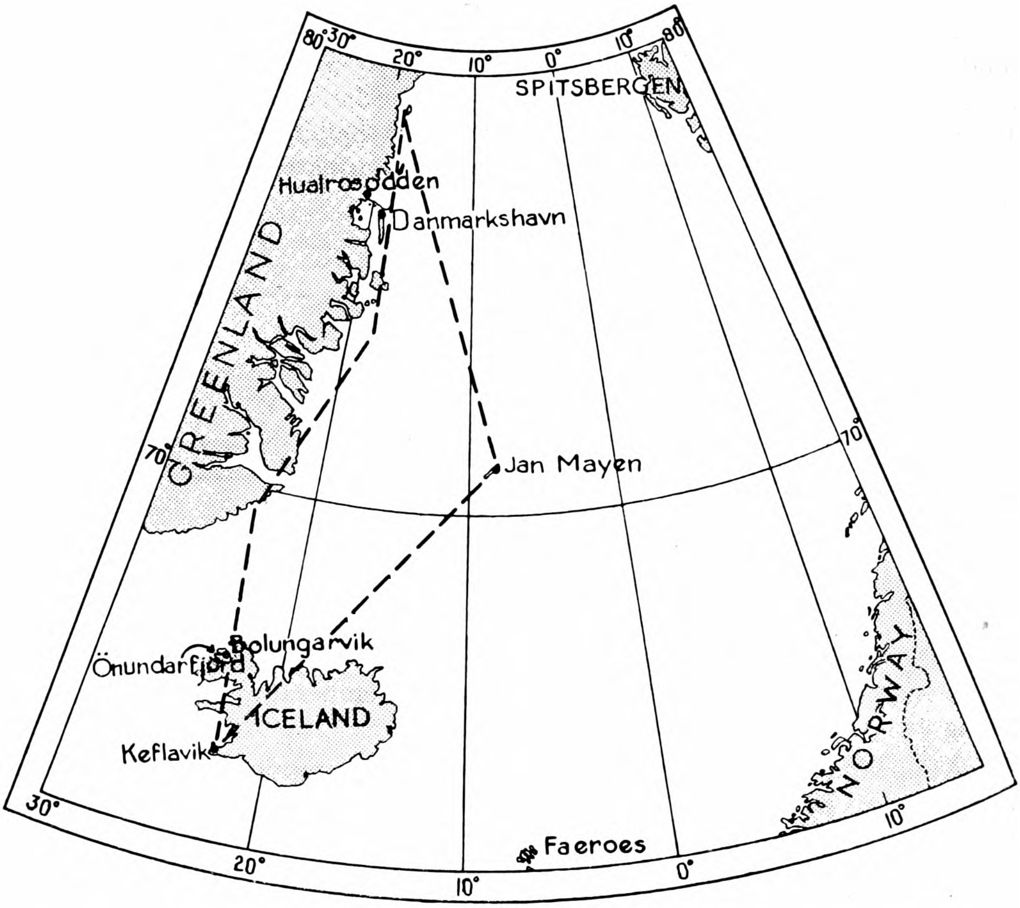
At 0600 the synoptic chart showed a deep but slowly filling depression off north-west Scotland, with unstable air on its western and southern sides. The gradient wind over the Cumberland coast was 230° 30 m.p.h.

B. H. IMRIE

May 16, 1951

Arctic flight by aircraft of R.A.F. Station, Shawbury

Special navigation exercises were carried out by members of No. Nine Specialist Navigation Course, Shawbury on March 13 and 15, 1951. The four Lancaster aircraft used for the flights were based at Keflavik, Iceland, having left Shawbury on March 9 and 11. The routes flown were the same on both days: Keflavik–Jan Mayen–79° 05′ N., 18° 00′ W.–74° N., 18° W.–69° 30′ N., 23° 30′ W.–Keflavik, being of 11 hours' duration. Time of take-off was 0430–0500 G.M.T.


80°
30°
20°
10°
0°
10°
80
SPITSBERGEN
Hualrosodden
Danmarkshavn
GREENLAND
70
Jan Mayen
70
Bolungarvik
Önundarfjord
ICELAND
Keflavik
NORWAY
Faeroes
30°
20°
10°
0°
10°

ROUTES OF THE SPECIAL NAVIGATION EXERCISES

From a weather point of view there were a number of interesting features on both flights. The " weather barrier " coincided with the sea-ice barrier on both days. This extended in a north-east–south-west direction at 74° 30′ N. on the track north of Jan Mayen and was recrossed at 69° 10′ N. on the track from Greenland to Iceland. On both days cloud broke completely over the ice although there was appreciable cloud over the sea and pack ice.

Flight of March 13.—There was much cumulus to 14,000 ft. over the open sea, but turbulence and icing were only slight on the northward legs. On the return to Iceland, however, severe turbulence and moderate icing were experienced in cumulus cloud which extended only to 8,000 ft.

On descent over the ice cap there was a 5° C. fall in temperature in the lowest 1,000 ft.

Visibility was extremely good except near the northern turning point and down the east coast of Greenland. Here all reports indicated the presence of " ice-crystal " haze which reduced visibility to very low limits. The haze extended from the surface to above 8,000 ft., almost obscuring the sun at times. The phenomenon extended to 72° N., at which point visibility improved rapidly.

Flight of March 15.—Cloud was much more shallow than on the previous flight, but an active front appears to have been crossed at 68° N. and recrossed on the southern route at 70° 15′ N. On this occasion visibility over the ice was excellent.

Temperatures at 8,000 ft. varied from −18° C. to −22° C. and a temperature of −46° C. was recorded at 20,000 ft. on crossing the front northwards. There were signs of marked katabatic effects on the east Greenland coast where local westerly surface winds appeared to undercut the prevailing easterly drift in places.

Fig. 1 (facing p. 228) shows a typical stretch of north Iceland, the Onundarfjórdur near the synoptic reporting station, Bolungarvik (66° 10′ N., 23° 15′ W.). Fig. 2 shows the area around the synoptic reporting station, Danmarkshavn (76° 46′ N., 18° 46′ W.), while Fig. 3 shows the station itself. It will be noted that the sea is completely frozen. Wind drifts of the snow can also be clearly seen indicating the prevailing wind direction. Shadows cast by the three radio masts stand out clearly. Fig. 4 shows a trapper's encampment at Hualrosodden (76° 56′ N., 20° 15′ W.) near to the station at Danmarkshavn. Musk ox were seen in the vicinity.

Grateful acknowledgement is made to Group Captain B. J. Roberts, Commandant, Shawbury, for permission to publish photographs taken during the flights.

A. BEYNON

Expedition to northern Norway

An interesting report on the meteorological observations made by the British Schools Exploring Society's expedition to northern Norway in August and September 1950 has been received from Mr. F. G. Hannell, of the Geography Department of Bristol University. Some notes on the more remarkable features of the report are given below.

The expedition visited the Kildetoppen Massif where the main observing station was installed on a moraine at 67° 45′ N., 16° 05′ E., at a height of 1,650 ft. above M.S.L. Eight subsidiary stations were installed at points at heights from 585 to 3,100 ft. above M.S.L. and arrangements made for twice-daily readings to be taken at all of them nearly simultaneously. Stevenson screens could not be taken because of the weight, and the thermometers were exposed in wooden boxes with holes bored in them above bulb level.

Remarkably high temperatures occurred between August 16 and 20 in a SE. air stream which had come from central Europe. The maximum temperature at the 588-ft. station on the 19th was 84° F. and at the 1,650-ft. station 78° F. The temperatures do not seem to have been seriously raised by the unorthodox exposure as the Swedish daily weather report gives high maxima in northern Sweden at this time, and on the west side of the mountain chain some föhn heating probably raised temperature further. During the period August 20–29 the station was under the influence of an anticyclone and marked inversion was noted. The minimum temperature during the day on August 23 was 4° F. lower at the 585-ft. station than at the 1,650-ft. one, and the minimum for the night August 22–23 was 19° F. lower. The mean night minimum for the period August 21–27 was 11° F. lower at the low-level station. Frost occurred at the 1,650-ft. station on four nights out of the 22 days on which the expedition took readings and the lowest minimum was 29° F. on the night September 1–2.

The main station measured only 1·09 in. rainfall in the 22 days, though the normal rainfall for August is between 2 and 3 in. in this area. Southern Norway and the British Isles experienced a very wet August.

Five auroral displays were seen, and two of them, on September 3 and 4 were entirely to the south of the zenith.

The Society is visiting central Iceland in the summer of 1951 and taking more extensive meteorological equipment lent by the Meteorological Office.

Random errors in standard observations

During 1949, at Kew Observatory, four sets of instruments, comprising wet, dry, maximum and minimum air thermometers in Stevenson screens, 4-in. and 8-in. soil and 1-ft. earth thermometers, and grass minimum thermometer, were maintained over a level grass site with apparently identical standard exposures. Readings of all thermometers were taken twice daily.

For the purpose of analysis the " correct " readings were taken to be the means of the four individual readings. The divergencies of the individual readings from the mean were then examined giving the following percentages within the 2σ range:—

Element	Time of observation	Proportion within 2σ range	2σ range
	G.M.T.	%	
Dry bulb	0930 and 1500	97·3	±0·4°F.
Minimum	0930	95·4	±0·3°F.
Maximum	1500	95·4	±0·5°F.
Grass minimum	0930	95·7	±1·6°F.
Relative humidity	0930 and 1500	96·8	±2 per cent.
Dew point	0930 and 1500	95·9	±0·9°F.
4-in. soil	0930	95·3	±0·4°F.
8-in. soil	0930	96·2	±0·4°F.
1-ft. earth	0930	95·7	±0·4°F.

The variance of the-dry bulb, soil and earth temperatures increased with increase of temperature. That of the extreme readings and the relative humidity showed little change, but the variance of the dew point decreased with increase of dew-point temperature.

In synoptic reports, temperatures are reported to the nearest whole degree. The possible frequency of divergence from the correct reading is as follows:—

	Reading low by				Reading high by			
	3°F.	2°F.	1°F.	Correct	1°F.	2°F.	3°F.	4°F.
				percentage frequency				
Dry Bulb <60°F.	...	...	5·6	89·1	5·3	...	...	...
Dry bulb ⩾60°F.	...	...	7·3	85·5	7·2	...	...	...
Minimum at 0930	...	...	5·1	89·4	5·5	...	...	...
Maximum at 1500	...	...	9·0	82·8	8·0	0·2	...	...
Grass minimum at 0930	0·1	2·8	24·5	51·3	17·0	2·8	1·3	0·2
Dew point at 0930 and 1500	...	0·6	14·6	71·1	13·1	0·6	...	...

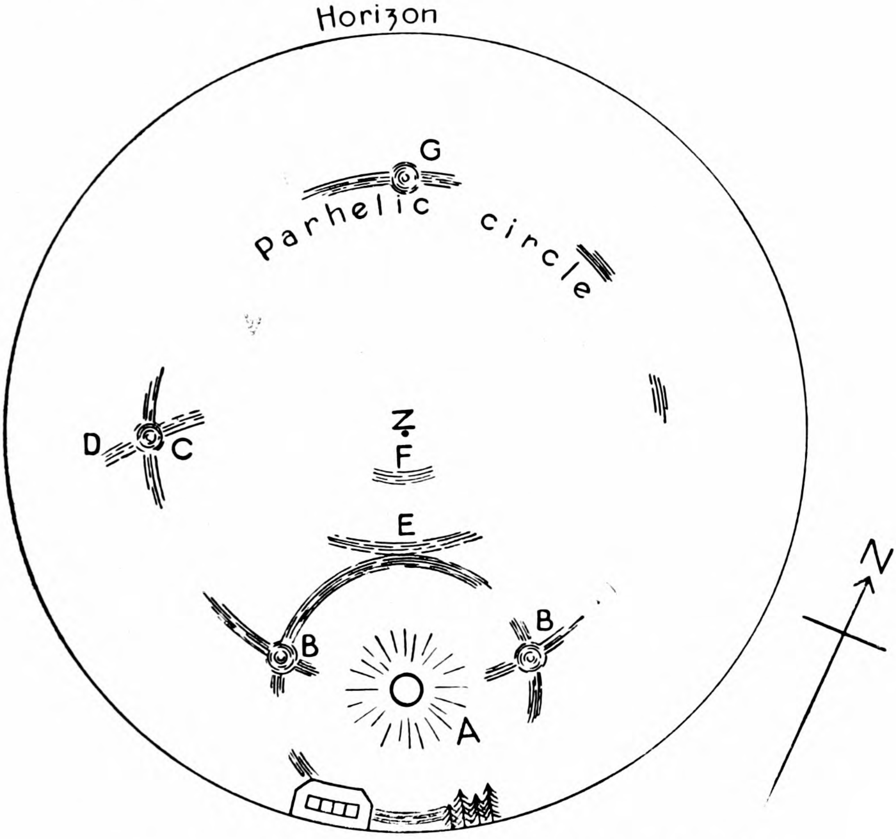
We may thus conclude that in synoptic reports a tolerance of plus or minus 1° F. may be admitted in dry-bulb, maximum and minimum temperatures, and dew points, and plus or minus 2° F. in grass minima.

A full report of the investigation will be published elsewhere.

L. P. SMITH

Halo phenomena at Gatow

Between 0950 and 1010 G.M.T. on Monday, February 19, 1951, a very unusual halo complex was observed from the meteorological office at Gatow near Berlin. This comprised a well defined, but broken, parhelic circle together with the two 22° mock suns, the 90° mock sun and a portion of the extremely rare 90° halo to the west and also the counter sun or anthelion. An almost complete 22° halo with upper arc of contact and the circumzenithal arc were also clearly visible. The upper arc of contact of the 22° halo was highly coloured but the circumzenithal arc was not coloured. The circumzenithal arc is usually brightly coloured.



HALO PHENOMENA AT GATOW, FEBRUARY 19, 1951

A	Sun.
B	Mock suns of 22° halo.
C	90° mock sun.
D	Possibly a small vertical arc of the 90° halo.
E	Arc of contact of 22° halo.
F	Circumzenithal arc.
G	Counter-sun or anthelion.
Z	Zenith.

The parhelic circle was particularly bright at the 90° mock sun.

This complex was also observed from the Potsdam Observatory where the easterly 90° mock sun was also seen.

Weather at the time was fair with 4 oktas cirrus and cirrostratus, well scattered, with some altocumulus and altostratus and some high stratocumulus at about 5,000 ft., making a total of 7 oktas and giving the sky a chaotic appearance.

A trough of low pressure along longitude approximately 4° E. was moving eastwards and reached the Berlin area at about 2100 G.M.T. with a period of slight rain.

Bulletin du Service Météorologique du Congo Belge

We welcome publication of the first number (January 1951) of the *Bulletin du Service Météorologique du Congo Belge.*

The first part of the bulletin consists of three articles: a comparison between the Campbell-Stokes and Marvin sunshine recorders by Dr. W. Schuepp leading to the conclusion that the former is the more effective in the tropics, a report on the distribution of thunderstorms over the Belgian Congo in 1945 by Dr. P. Goedert, and a note by M. G. Heinrichs on the terrestrial magnetic observations made at Elisabethville between 1938 and 1950.

The second part of the *Bulletin* consists of a report on the weather of January 1951 in the Belgian Congo and the district of Ruanda-Urundi. In this part daily maximum and minimum temperatures, rainfall and sunshine are given in diagrams. Monthly wind roses for the surface and for varying heights in the atmosphere to 7,800 m. for Costermansville are also provided.

REVIEWS

Report on the snow survey of Great Britain for the season 1949–50. By E. L. Hawke and D. L. Champion. *J. Glaciol., London.* **1**, 1951, pp. 516–26, *Illus.*, British Glaciological Society, London. Offprint. Price: 2*s.* 6*d.*

The annual report of the Snow Survey of Great Britain for the period September 1949 to September 1950, published in the *Journal of Glaciology* contains besides the usual month by month description of snowfall and notes on the duration of mountain snow cover an interesting new section on snowfall in British coastal waters based on observations taken on lightships.

The highlight of the year was the heavy snowfall of April 26, 1950, south of the Thames.

No snow at all fell on the "Seven Stones" lightship off Cornwall or, more surprisingly, on the "Helwick" and "English and Welsh Grounds" lightships in the Bristol Channel. The latter ship is only some 5 miles from land about midway between Cardiff and the Somerset coast.

We extend our congratulations to Messrs. Hawke and Champion on this valuable report.

G. A. BULL

Weather and the building industry. A Research Correlation Conference on climatological research and its impact on building design, construction, materials and equipment held at the National Academy of Sciences. *Res. Conf. Rep., Washington D.C.*, No. 1, 1950, 10¾ in. × 8¼ in., pp. viii + 159, *Illus.* Building Research Advisory Board, National Research Council, Washington D.C. Price: $3.50.

The importance assigned to weather and climate in the design and construction of houses in America is shown by their being made the subject of the first of a series of conferences arranged by the Building Research Advisory Board of the United States, which was attended not only by builders, architects and engineers, but also by such well known meteorologists as Dr. Reichelderfer and Dr. Landsberg. The Conference produced a good deal of useful and interesting information, but even more food for thought, on both sides of the fence. The meteorologists said with one voice: " Tell us what you want, and we will provide it." The architects replied with almost equal unanimity: " Yes, but provide it in a form that we can use." The Report of the Conference is published partly with the aid of a grant from the far-seeing management of the magazine *House Beautiful*, and it is worthy of remark that the most helpful effort at bridging the gap between climate and the home originated from research undertaken by this magazine. This was a paper by Dr. Paul Siple, " Climatic criteria for building construction", which sets out a striking series of monthly diagrams of frequencies and extremes—air temperature and dew point, sunshine, wind, precipitation, relative humidity and vapour pressure. It also included such necessary data, to the wise planner, as elevation and azimuth of the sun. A notable (and noticed) omission was snowfall. The specimen published is for Phoenix, Arizona, but similar diagrams have been prepared for a number of other cities, and all are being published in the *Bulletin of the American Institute of Architecture*, with text explaining their impact on architecture and construction.

It came out repeatedly in the Conference that extremes and frequencies are both needed, but not averages. " Nature does not produce averages, the statistician does that." Extremes are wanted so that the architect shall know what his building may have to stand up to, but even so, there was diversity of opinion (from 100 years downwards) as to how long it had to stand up for. Frequencies are needed so that the house may be most comfortable for the greatest possible part of the time. Comfort, in this context, is defined as not noticing the environment. It depends to some extent on clothing, and one speaker remarked that as fashion decrees more and more scanty clothing, so the " comfortable " temperature rises. Moreover, it is very doubtful how far statistics, even frequencies of single elements, are safe guides. Statistics of wind lose much of their value unless we know the temperature distribution with each speed from each direction, and how often it is accompanied by sunshine, rain and snow. Such combined statistics are very costly to obtain by hand tabulation; in fact they are only possible to any appreciable extent by machine analysis of punched cards. Delegates heard a great deal about the eighty million cards collected by the Weather Bureau, but even these only permit analysis of five years' data. Little was heard about the more scientific approach by the study of frequency distributions of correlated series, but this may actually turn out to be the answer.

The difficulty does not end with the production of suitably digested figures for conventionally exposed climatological stations. Dr. Landsberg (" Microclimatic research in relation to building construction ") rammed home the fact, still too little realized, that there may be a whole range of climates within the confines of a single city, and the differences may be equivalent to changes of location by hundreds of miles. Moreover, he and several other speakers showed how, by the suitable placing of grass and cement, windows, walls and trees, the microclimate of a house can be modified both outside and in. The thermal capacity and heat transmission of the walls are especially important, for analysis showed that in winter a house loses four fifths of its heat through the walls and only one fifth by ventilation.

The cheapest way of providing homes is by mass-produced buildings from standard parts and materials, but the climates of the United States are so various that no one type can operate at maximum efficiency in all States, and some degree of designing for climate is essential. It is true that central heating, air conditioning and other " gadgets " can rectify almost any fault in design, but the architect's aim should be to foresee the climatic extremes and as far as possible minimise them without mechanical power. You don't do this by planting a Cape Cod house in a southern prairie.

One speaker from the building side advised his colleagues: " Don't throw out the climatologist too soon." Dr. Reichelderfer went further: " Don't throw him out at all, take him into your inmost councils." That is, in essence, the moral of this pioneer Conference.

C. E. P. BROOKS

The Shira Plateau of Kilimanjaro. By George Salt. *Geogr. J., London,* **117**, 1951, pp. 150–166.

The article by Dr. Salt in the June 1951 number of the *Geographical Journal* on the Shira plateau situated at 13,000 to 15,000 ft. above M.S.L. on the western side of Kilimanjaro includes sections on the climate of the plateau and on the glaciation of the Kibo summit of the mountain.

Dr. Salt visited the area in 1948 and found that the glaciers have receded very greatly since they were first studied at close quarters by Meyer and others in the 1890's. He estimates that if they continue to recede at the same rate there will be no ice-cap left by the end of another fifty years.

He notes that, by day, rising currents of warm air brought cloud up from the lower forest zone of the mountain and the plateau was usually walled with cloud on the south after midday. At night a cold down-current from the ice-cap above was observed. Frost occurred at night and rime formed on vegetation and ice on pools of water. The lowest temperature observed was −2° C.

G. A. BULL

BOOKS RECEIVED

The geomagnetic field of the Netherlands reduced to 1945·0. By Dr. J. Veldkamp. Koninklijk Nederlands Meteorologisch Instituut. 13¼ in. × 9½ in., pp. 30+7 charts, 17 in. × 13¼ in. Staatsdrukkerij-en Uitgeverijbedrijf 's-Gravenhage, 1951. Price: *fl.* 5.00.

Jaarboek B. Aardmagnetisme (Yearbook, B. Geomagnetism) 1947, Koninklijk Nederlands Meteorologisch Instituut. 13¼ in.×9½ in., pp. iv+28, Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage, 1950. Price: *fl.* 3.00.

Annual Report for 1941. Magnetic and meteorological results for 1948. Apia Observatory. 6 in.×9½ in. pp. iv+170 and vi+154. New Zealand Department of Scientific and Industrial Research, Wellington, 1950.

NEWS IN BRIEF

Mr. W. Evetts, rainfall observer of Hampton, Tackley, Oxford, has for disposal a Stevenson screen and thermometers, also grass minimum and solar radiation thermometers. He will be pleased to hear from anyone willing to purchase these.

ROLL OF HONOUR OF METEOROLOGICAL OFFICE STAFF

It has been decided to prepare a Roll of Honour inscribed with the names of the staff of the Meteorological Office who lost their lives during the recent war. The dates for the duration of the war are those adopted by the Royal Air Force for the same purpose, September 3, 1939, to December 31, 1947. The following list of 63 names, which includes both members of H.M. Forces and civilians, has been prepared after exhaustive examination of documents and reference to individuals serving in the various theatres of war. Nevertheless, corrections may be necessary and there may be omissions. If any are noticed by readers, the Director would be glad to have the information.

Bankier, Lili Stefania	Palestine
Beuttell, Robert Gerard	Tiree
Blackburn, Edmund	At sea
Blagrove, Stanley	At sea
Brown, David Thomas	Chivenor
Brunning, Thomas Charles Joseph	Biggin Hill
Butfield, Edwin Henry Frederick	Biggin Hill
Campbell, Alastair William	Docking
Cartwright, Geoffrey	Tiree
Clark, Sydney John	Holland
Clifford, Norman John	At sea
Crichton-Miller, Campbell	Netheravon
Curd, Charles Daniel	Bircham Newton
Davidson, Jack	Tain
Edington, William Malcolm	North Africa
Fielding, Richard Allan	Iceland
Gange, Frank Cecil	India
Goatly, Percy Bernard	At sea
Gordon, John Macilrick Bryce	Brawdy
Groves, Louis Grimble	Brawdy
Halford, Glyn	Lichfield
Hedley-Smith, Edwin James	At sea
Henderson, William Milton	Malta
Hewitson, Donald Parr	Tiree
Hill, Joan Ellen	London
Holmes, Clive Douglas	India
Joseph, Peter Bernard	Turnberry
Legg, David Christian	Stradishall
Leigh-Clare, Howard Harry John	St. Davids
McCulloch, John Godbolt	East Africa
Martin, Richard Turner	Brawdy
Merridale, Reginald George	Holland
Montgomery, Robert Eckford	Bicester
Moore, Edward	Defford
Morse, Olive Mary	York
Mulligan, David Thomas	Brawdy
Nash, Robert Joseph	At sea
Portass, Sidney Leslie	At sea
Pressley, Dennis Alfred	Wick
Proud, Stanley	At sea
Pye, John Edward Bartle	St. Davids
Read, Harry	At sea
Rees, Meurig Thomas	Northwood
Rivers, Frederick Alan	At sea
Roberts, Norman Arthur	Biggin Hill
Rutherford, Richard	Snaith
Sharp, David Mountford	At sea
Short, Percy William Henry	At sea
Simmonds, Anthony Richard	Iceland
Smith, Peter Geoffrey	Tiree
Stevenson, Roy	Tiree
Tagg, Kenneth Thomas	Wattisham
Taylor, John Russell	Aden
Thom, Forbes Vivian	At sea
Thomas, Graham Nicholson	Aldergrove
Thompson, Albert Alexander	Aldergrove
Thomson, Keith Kilbourne	Tiree
Thorpe, Frederick Housden	Egypt
Trevitt, Kenneth	Langham
Watson, Collin George	At sea
Willis, Alfred James	Hornchurch
Wrighton, Richard Henry Roland	At sea
Vann, Arthur Hugh	North Africa

METEOROLOGICAL OFFICE NEWS

Agricultural Shows.—For the first time since 1935, an exhibit was staged by the Office at the Royal Highland Show, held this year at Aberdeen on June 19–22. Members of the staff from the Headquarters Branch dealing with agricultural meteorology and from the offices at Edinburgh and Dyce were on duty at the exhibit which formed part of the display organized by the North of Scotland College of Agriculture. The visitors, who came from all parts of Scotland, showed considerable interest in the instruments and models, especially in a working model of a wind-tunnel showing the different shelter-effects of a wall and a hedge. The wind-tunnel was also displayed at the Royal Cornwall Show at Newquay on July 11 and 12.

Visitors to Eskdalemuir Observatory.—On the 16th of May, 35 members of the Royal Meteorological Society (Scottish Branch) and their friends met at Eskdalemuir Observatory, and, under the guidance of the staff, visited in turn the huts for absolute magnetic measurements, the underground house containing the magnetographs, the rain and snow recorders, the radiation instruments and the atmospheric-potential recorder. Fine weather, the smooth efficiency of the arrangements, and the generosity of Mr. and Mrs. Crichton in providing tea for the party, all combined to make the visit a pleasant and memorable occasion.

Meteorological Association.—The summer meeting of the Meteorological Association was held at the Meteorological Office, Harrow, on Saturday, June 30. Some 55 members of the Association were received by the Director, who is also President of the Association, and Lady Johnson.

All branches at Harrow gave an exhibition of their work and tea was served in the canteen. Many war-time friendships were renewed in the course of the afternoon.

Much travelled.—A mysterious loss of correspondence addressed to Benbecula, Outer Hebrides, has been cleared up by its return from the New Hebrides in the south-west Pacific seven months after posting.

WEATHER OF JUNE 1951

Mean pressures were below 1020 mb. generally. They were between 1015 and 1020 mb. over western Europe except Scandinavia and mainly between 1010 and 1015 mb. over most of North America, the North Atlantic, Scandinavia and west Africa.

The area showing the greatest excess of pressure above normal was over the North Atlantic, north of 60° N., and Scandinavia, the excess varying from 2 to 5 mb. The largest deficit of pressure below normal occurred over the North Atlantic south of 60° N., the amount reaching 7 mb. in places.

Mean temperatures varied from 50° to 60° F. over most of Scandinavia and the British Isles, 60° to 70° F. over the rest of Europe, and 70° to 80° F. over the Mediterranean and north Africa. Departures from normal temperature were generally small; over west Europe they were about 1° to 2° F. above normal in places.

The weather in the British Isles was sunny generally and dry on the whole, though rainfall exceeded the average over part of Northern Ireland, much of east Scotland and in scattered places elsewhere.

During the first eight days a ridge of high pressure extended southward over the British Isles from an anticyclone in the north; the weather was unusually sunny, and dry apart from some slight rain and local thunder in the extreme south-west of England and Wales and at Guernsey on the 7th and 8th. Day temperatures were not particularly high except in the west and north-west (78° F. at Rothesay and Garvagh on the 4th, 81° F. at Glasgow, 79° F. at Glenbranter and 78° F. at Helensburgh and Paisley on the 5th and 78° F. at Ambleside on the 6th), while minimum temperatures were low at times (24° F. at Budden Ness on the 1st and Glenlivet on the 8th and 27° F. at Kielder Castle, Northumberland on the 1st and 2nd). On the 7th easterly winds of polar origin caused a considerable fall in temperature, by as much as 15° F. in the maximum at some places. On the 9th and 10th small depressions over southern Ireland and the southern North Sea were associated with rain in the south of Ireland and in England and Wales and local thunderstorms in England, but the weather continued dry and sunny on the whole in Northern Ireland and most of Scotland. From the 11th to the 14th Atlantic depressions moved north-east off our north-west seaboard, while secondary troughs of low pressure crossed the country. Rain fell in most areas on the 11th and 12th and in the north and west also on the 13th, while scattered rain or showers occurred on the 14th. Thunderstorms were rather widespread on the 12th. On the 16th and 17th a depression westward of Ireland moved east and turned north-east; rain fell generally except in east and south-east England and thunderstorms were recorded, chiefly in the west and north. Subsequently an anticyclone off our south-west coasts moved east-north-east to central Europe, while a trough associated with a depression west of Scotland moved across the country. Scattered showers, a few local thunderstorms and long sunny periods occurred on the 19th and rain, heavy locally in the north-west, on the 20th, but in the southern half of England the 20th was dry and sunny. Between the 21st and 26th a complex depression moved from Spain to Brittany, thence to the Low Countries and finally slowly northwards over the North Sea. Unsettled thundery weather prevailed for the most part and rainfall was heavy locally in east Scotland on the 25th (2·92 in. at Glenferness, Nairnshire and 2·88 in. at Keith, Banffshire). Thereafter a ridge of high pressure off our north-west coasts moved in over the British Isles, while a small depression off south-west Ireland moved east-south-east. Fair weather prevailed apart from rain in a few places in the south of England on the 28th. By the 30th the anticyclone was centred over England and the fair weather persisted except in the north-west and extreme north of Scotland, where weak troughs of low pressure caused some rain.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	78	27	+0·3	55	−3	116
Scotland	81	24	−0·6	85	−3	109
Northern Ireland ...	78	35	+0·3	101	−3	120

RAINFALL OF JUNE 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·16	57	*Glam.*	Cardiff, Penylan ...	·67	27
Kent	Folkestone, Cherry Gdn.	1·65	83	*Pemb.*	Tenby	·99	41
,,	Edenbridge, Falconhurst	2·53	115	*Card.*	Aberystwyth	2·22	91
Sussex	Compton, Compton Ho.	3·00	120	*Radnor*	Tyrmynydd	1·23	38
,,	Worthing, Beach Ho. Pk.	1·88	107	*Mont.*	Lake Vyrnwy	1·96	61
Hants.	Ventnor Cemetery ...	1·37	72	*Mer.*	Blaenau Festiniog ...	3·87	60
,,	Bournemouth	·54	27	*Carn.*	Llandudno	1·14	60
,,	Sherborne St. John ...	·64	30	*Angl.*	Llanerchymedd ...	·87	37
Herts.	Royston, Therfield Rec.	1·26	56	*I. Man*	Douglas, Borough Cem.	·89	37
Bucks.	Slough, Upton	1·15	56	*Wigtown*	Port William, Monreith	1·91	81
Oxford	Oxford, Radcliffe ...	1·41	63	*Dumf.*	Dumfries, Crichton R.I.	1·35	53
N'hants.	Wellingboro' Swanspool	·99	47	,,	Eskdalemuir Obsy. ...	2·44	77
Essex	Shoeburyness	1·13	64	*Roxb.*	Kelso, Floors	1·55	73
,,	Dovercourt	1·18	67	*Peebles*	Stobo Castle	1·49	64
Suffolk	Lowestoft Sec. School ...	1·99	110	*Berwick*	Marchmont House ...	1·01	44
,,	Bury St. Ed., Westley H.	1·41	67	*E. Loth.*	North Berwick Res. ...	1·70	102
Norfolk	Sandringham Ho. Gdns.	1·71	79	*Midl'n.*	Edinburgh, Blackf'd. H.	1·41	70
Wilts.	Aldbourne	·97	42	*Lanark*	Hamilton W. W., T'nhill	2·32	105
Dorset	Creech Grange... ...	·55	24	*Ayr*	Colmonell, Knockdolian	1·51	60
,,	Beaminster, East St. ...	·95	42	,,	Glen Afton, Ayr San. ...	1·51	50
Devon	Teignmouth, Den Gdns.	·82	43	*Bute*	Rothesay, Ardencraig ...	2·65	86
,,	Cullompton	1·17	55	*Argyll*	Morvern (Drimnin) ...	1·95	63
,,	Ilfracombe	·98	45	,,	Poltalloch	2·74	90
,,	Okehampton Uplands	1·92	69	,,	Inveraray Castle ...	2·79	70
Cornwall	Bude, School House ...	·51	25	,,	Islay, Eallabus	1·90	73
,,	Penzance, Morrab Gdns.	·59	27	,,	Tiree	1·71	67
,,	St. Austell	·81	31	*Kinross*	Loch Leven Sluice ...	2·63	120
,,	Scilly, Tresco Abbey ...	1·11	64	*Fife*	Leuchars Airfield ...	1·51	90
Glos.	Cirencester	1·30	54	*Perth*	Loch Dhu	4·14	99
Salop.	Church Stretton ...	·79	31	,,	Crieff, Strathearn Hyd.	2·38	90
,,	Shrewsbury	1·02	49	,,	Pitlochry, Fincastle ...	1·79	86
Worcs.	Malvern, Free Library	·64	28	*Angus*	Montrose, Sunnyside ...	1·88	113
Warwick	Birmingham, Edgbaston	1·13	49	*Aberd.*	Braemar	1·22	62
Leics.	Thornton Reservoir ...	1·18	55	,,	Dyce, Craibstone ...	2·11	113
Lincs.	Boston, Skirbeck ...	·91	50	,,	Fyvie Castle	2·89	138
,,	Skegness, Marine Gdns.	1·08	60	*Moray*	Gordon Castle	2·85	140
Notts.	Mansfield, Carr Bank ...	·91	40	*Nairn*	Nairn, Achareidh ...	1·67	94
Derby	Buxton, Terrace Slopes	2·49	77	*Inverness*	Loch Ness, Garthbeg ...	2·50	110
Ches.	Bidston Observatory ...	·61	28	,,	Glenquoich	4·18	85
Lancs.	Manchester, Whit. Park			,,	Fort William, Teviot ...	2·96	83
,,	Stonyhurst College ...	1·37	45	,,	Skye, Duntuilm ...	2·18	84
,,	Squires Gate	·59	28	*R. & C.*	Tain, Tarlogie House ...	1·32	71
Yorks.	Wakefield, Clarence Pk.	·71	33	,,	Inverbroom, Glackour...	1·60	57
,,	Hull, Pearson Park ...	1·32	64	,,	Applecross Gardens ...	3·41	119
,,	Felixkirk, Mt. St. John...	1·28	58	,,	Achnashellach	3·12	83
,,	York Museum	1·08	52	,,	Stornoway Airfield ...	2·34	106
,,	Scarborough	1·00	54	*Suth.*	Loch More, Achfary ...	4·90	132
,,	Middlesbrough... ...	1·58	84	*Caith.*	Wick Airfield	·83	46
,,	Baldersdale, Hury Res.	·86	36	*Shetland*	Lerwick Observatory ...	1·40	78
Norl'd.	Newcastle, Leazes Pk....	2·21	105	*Ferm.*	Crom Castle	3·20	118
,,	Bellingham, High Green	1·27	55	*Armagh*	Armagh Observatory ...	2·11	84
,,	Lilburn Tower Gdns. ...	1·15	56	*Down*	Seaforde	1·85	67
Cumb.	Geltsdale	1·79	66	*Antrim*	Aldergrove Airfield ...	2·70	112
,,	Keswick, High Hill ...	2·26	78	,,	Ballymena, Harryville...	3·29	113
,,	Ravenglass, The Grove	1·05	40	*L'derry*	Garvagh, Moneydig ...	3·44	135
Mon.	Abergavenny, Larchfield	·35	14	,,	Londonderry, Creggan	2·15	76
Glam.	Ystalyfera, Wern House	2·28	60	*Tyrone*	Omagh, Edenfel ...	2·78	99

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FIRST YEAR OF UPPER AIR OBSERVATIONS BY OCEAN WEATHER SHIPS

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Introduction.—The following note deals with the first year's radio-sonde observations made from the British ocean weather stations ITEM and JIG.

Observations were actually started in August 1947 at station JIG (nominal position 53° 50′ N., 18° 40′ W.) and in September 1947 at station ITEM (nominal position 60° N., 20° W.) but there were frequently considerable gaps in the records, owing to the fact that all four weather ships were not then in operation, and for this note the first year has been taken as January–December 1948. The observations used have been restricted to those made when the ships were within ½° of latitude and 1° of longitude of the centre of the I.C.A.O. grid.*

Upper air temperatures.—*Monthly mean and extreme values and extremes for the year.*—Monthly means and extremes for stations JIG and ITEM are given in Table I. As the number of observations falls off rapidly at levels above 300 mb. (30,000 ft.) values have only been given for levels up to 100 mb. (53,000 ft.). Corresponding mean values for Fazakerley (53° 28′ N., 2° 55′ W.) and Lerwick (60° 08′ N., 1° 11′ W.) are also shown in Table I for comparison. Average temperatures for the period 1942–48 are also given for Fazakerley and Lerwick to enable an estimate to be made, if required, of the average temperature over the ocean weather stations.

Graphs of mean monthly temperatures at standard pressure levels are given to make it easier to study the annual variation and differences between the ocean weather stations and the corresponding land stations; these graphs are shown in Fig. 1. Periods when the air was colder over the sea than over the land have been stippled. This stippling shows that, in the troposphere, the upper air was usually colder over station JIG, than over Fazakerley during the winter and warmer during the summer. This was rather surprising as it would have been reasonable to expect the opposite in the lower layers of the troposphere since, in general, the sea is warmer than the land in the winter months and *vice versa* in the summer months. Comparison of the curves for station ITEM with those for Lerwick is more in accordance with expectation, and shows definitely lower upper air temperatures up to 700 mb. from January to March

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*An I.C.A.O. grid is a 210-nautical-mile square which is divided into squares with sides 10 nautical miles. The nominal position of the ocean weather station is at the centre of the central square; i.e. the centre of the grid.

TABLE I—MONTHLY MEAN AND EXTREME UPPER AIR TEMPERATURES

Ocean weather station JIG (53° 50′ N., 18° 40′ W.)

Year: 1948

Pressure level	Station JIG				Fazakerley		Station JIG				Fazakerley		Station JIG				Fazakerley		Station JIG				Fazakerley		Pressure level
	Temperature Mean	Temperature Max.	Temperature Min.	No. of obs.	Mean temperature 1948	Mean temperature 1942–48	Temperature Mean	Temperature Max.	Temperature Min.	No. of obs.	Mean temperature 1948	Mean temperature 1942–48	Temperature Mean	Temperature Max.	Temperature Min.	No. of obs.	Mean temperature 1948	Mean temperature 1942–48	Temperature Mean	Temperature Max.	Temperature Min.	No. of obs.	Mean temperature 1948	Mean temperature 1942–48	
mb.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	mb.
			JANUARY						FEBRUARY						MARCH						APRIL				
100	−66·9	−51	−85	22	−65·4	−72·6	−62·4	−44	−72	14	−65·5	−70·9	−63·1	−54	−74	21	−65·5	−67·5	−58·5	−39	−73	16	−57·9	−64·2	100
150	−62·3	−44	−99	32	−61·7	−70·0	−61·9	−47	−73	21	−62·4	−69·2	−61·7	−38	−79	46	−65·9	−67·3	−56·0	−39	−79	35	−54·0	−63·4	150
200	−60·4	−44	−85	49	−63·5	−72·2	−65·1	−51	−82	34	−62·8	−72·6	−67·9	−35	−86	68	−72·4	−72·4	−60·8	−39	−89	51	−56·5	−67·3	200
300	−60·3	−44	−76	59	−58·5	−58·4	−56·7	−39	−67	52	−53·9	−57·9	−51·6	−36	−62	86	−50·6	−56·4	−49·9	−34	−65	87	−50·8	−52·3	300
400	−38·7	−18	−57	85	−35·9	−35·0	−29·1	−15	−42	67	−32·7	−34·1	−27·2	−15	−48	102	−25·4	−30·5	−27·4	−10	−42	102	−29·7	−27·3	400
500	−18·7	2	−36	90	−14·7	−14·5	−9·1	8	−34	72	−12·7	−13·7	−7·1	6	−29	103	−3·8	−9·4	−8·0	10	−29	102	−9·5	−6·7	500
600	−2·1	16	−18	90	2·2	1·8	6·5	25	−11	73	4·1	2·5	8·6	22	−9	105	11·6	6·7	7·3	25	−12	102	7·3	9·2	600
700	11·4	25	−1	91	15·0	14·9	17·0	33	1	72	16·1	15·0	21·1	35	8	106	24·9	19·1	19·3	35	−1	103	20·1	21·3	700
800	23·0	38	14	91	24·3	24·5	25·5	38	11	72	25·0	24·4	30·3	46	13	106	34·2	28·5	28·3	47	11	103	29·4	30·4	800
850	28·4	41	18	91	29·5	...	29·2	42	19	72	28·1	...	34·3	53	18	106	38·0	...	31·8	52	16	103	33·5	...	850
900	34·6	47	25	91	35·2	32·8	33·6	47	26	73	30·9	31·1	38·6	61	25	106	42·4	35·9	35·9	49	23	103	39·0	39·1	900
			MAY						JUNE						JULY						AUGUST				
100	−60·7	−44	−82	45	−55·5	−59·3	−55·7	−42	−72	41	−54·7	−57·8	−57·3	−42	−76	66	−58·3	−57·5	−52·1	−33	−64	75	−54·8	−57·8	100
150	−60·5	−43	−82	73	−56·3	−59·5	−55·2	−36	−83	58	−52·8	−58·1	−60·2	−45	−78	85	−58·9	−57·6	−53·7	−38	−67	95	−56·1	−58·8	150
200	−63·8	−43	−82	88	−60·3	−62·7	−56·1	−32	−87	74	−56·1	−60·1	−63·0	−41	−76	93	−58·9	−59·8	−55·7	−33	−78	103	−57·9	−59·4	200
300	−49·6	−36	−66	111	−49·5	−50·5	−42·3	−26	−58	98	−43·7	−45·0	−38·9	−23	−52	102	−41·4	−41·8	−44·1	−30	−56	111	−45·1	−42·1	300
400	−24·8	−11	−47	120	−25·7	−26·4	−19·1	1	−43	112	−20·7	−20·7	−12·7	1	−35	114	−15·8	−16·2	−18·6	−7	−37	121	−18·5	−15·9	400
500	−4·6	8	−26	121	−4·8	−5·6	0·1	22	−18	115	−1·4	−0·6	7·3	19	−12	116	4·1	4·1	1·9	11	−16	122	2·0	4·7	500
600	10·8	27	−12	121	12·1	10·8	15·3	33	1	115	14·4	15·1	22·3	33	6	117	19·7	20·0	17·6	28	4	123	17·7	20·2	600
700	22·7	44	1	122	24·7	23·3	27·0	42	13	115	26·6	27·1	34·1	47	18	117	31·7	32·0	29·9	47	17	123	30·0	32·4	700
800	32·3	52	14	122	34·2	33·2	35·5	53	21	115	35·3	36·1	43·0	54	27	117	40·1	41·0	38·7	48	29	123	38·5	41·7	800
850	36·3	56	20	122	39·0	...	38·9	58	25	115	39·8	...	46·3	59	33	117	43·9	...	42·0	52	34	123	43·0	...	850
900	39·7	62	26	122	43·8	42·7	42·6	61	32	115	44·7	45·2	48·3	61	35	117	48·3	49·4	46·4	55	37	123	47·5	50·5	900
			SEPTEMBER						OCTOBER						NOVEMBER						DECEMBER				
100	−65·9	−35	−86	72	−67·5	−63·6	−71·2	−48	−88	51	−70·0	−71·5	−73·2	−59	−88	60	−77·5	−75·6	−69·0	−51	−94	55	−70·5	−74·1	100
150	−67·7	−25	−100	95	−69·3	−64·6	−68·9	−40	−86	77	−70·3	−71·3	−69·9	−54	−91	77	−77·6	−74·0	−65·9	−45	−100	70	−68·5	−73·0	150
200	−64·1	−32	−84	100	−66·1	−63·5	−64·8	−34	−83	89	−66·5	−68·3	−70·1	−52	−96	93	−74·9	−72·6	−66·6	−41	−103	77	−69·5	−74·6	200
300	−37·5	−20	−55	110	−39·7	−43·2	−45·7	−19	−77	107	−46·6	−47·2	−51·4	−36	−69	107	−50·7	−52·8	−55·4	−36	−77	81	−53·9	−56·5	300
400	−12·3	8	−29	115	−13·7	−17·0	−21·9	1	−52	118	−20·8	−21·9	−26·4	−10	−52	117	−24·5	−27·8	−32·1	−15	−51	82	−29·5	−32·1	400
500	7·1	29	−9	115	6·1	3·4	−2·1	18	−28	119	−1·9	−1·3	−5·9	8	−24	117	−3·3	−7·2	−11·4	4	−32	82	−8·5	−11·1	500
600	22·0	40	6	115	21·3	18·2	13·4	30	−12	119	13·5	14·6	10·2	24	−7	117	13·3	8·4	4·9	18	−14	82	8·7	5·2	600
700	33·4	54	20	115	32·4	29·9	24·9	43	1	119	24·9	26·9	23·1	38	8	117	25·7	20·5	18·8	34	3	82	21·7	18·2	700
800	41·3	58	28	115	40·1	38·5	33·3	57	14	119	33·1	35·9	33·0	47	21	117	35·5	30·0	27·9	42	15	82	32·3	27·8	800
850	43·9	60	34	115	42·5	...	36·8	55	21	119	36·9	...	37·2	51	22	117	39·4	...	32·1	47	20	82	36·3	...	850
900	46·4	59	39	115	46·1	46·4	41·3	59	28	119	41·7	43·0	41·8	57	32	117	43·5	37·9	37·2	50	28	82	39·7	35·5	900

Note.—On a number of occasions, observations were missed between 850 and 700 mb.

TABLE I—*continued*

Ocean weather station ITEM (60° N., 20° W.) **Year:** 1948

Pressure level	Station ITEM				Lerwick		Station ITEM				Lerwick		Station ITEM				Lerwick		Station ITEM				Lerwick		Pressure level
	Temperature			No. of obs.	Mean temperature		Temperature			No. of obs.	Mean temperature		Temperature			No. of obs.	Mean temperature		Temperature			No. of obs.	Mean temperature		
	Mean	Max.	Min.		1948	1942–48	Mean	Max.	Min.		1948	1942–48	Mean	Max.	Min.		1948	1942–48	Mean	Max.	Min.		1948	1942–48	
mb.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	mb.
	JANUARY						FEBRUARY						MARCH						APRIL						
100	−81·2	−72	−91	11	−68·9	−73·4	−74·7	−64	−84	10	−66·6	−73·4	−61·3	−48	−70	16	−67·2	−68·4	−53·9	−42	−65	41	−54·8	−58·9	100
150	−74·4	−63	−89	30	−64·6	−69·9	−73·1	−61	−93	14	−63·4	−70·4	−58·8	−40	−72	27	−65·3	−66·3	−51·2	−38	−67	54	−51·7	−57·9	150
200	−72·2	−61	−91	34	−64·1	−71·4	−73·3	−60	−93	18	−64·8	−72·1	−66·2	−35	−88	32	−70·6	−69·7	−51·3	−36	−81	63	−53·9	−61·5	200
300	−71·2	−57	−82	36	−64·0	−62·2	−59·8	−46	−69	24	−60·0	−62·3	−52·2	−44	−62	34	−55·5	−59·5	−51·1	−22	−67	81	−51·8	−54·1	300
400	−47·3	−22	−60	38	−45·9	−39·9	−33·6	−22	−45	28	−37·0	−40·0	−28·9	−18	−51	37	−32·1	−36·5	−33·8	−18	−52	95	−34·4	−32·4	400
500	−25·3	−7	−39	38	−25·1	−20·1	−12·4	3	−24	29	−15·8	−20·2	−8·2	4	−32	37	−11·9	−16·6	−15·9	2	−34	96	−14·8	−12·7	500
600	−6·5	8	−18	39	−8·3	−4·0	4·7	18	−7	29	0·7	−4·0	8·0	20	−20	37	4·2	−0·7	−1·7	18	−22	96	1·9	3·0	600
700	9·1	21	0	40	7·1	9·4	17·4	30	5	29	13·5	9·0	21·1	32	−2	37	17·5	12·4	10·3	29	−3	96	14·9	15·4	700
800	21·1	27	11	40	18·2	19·6	27·2	41	16	29	22·7	19·1	31·6	45	12	36	28·8	22·3	19·6	38	8	96	25·9	25·1	800
850	26·5	33	18	40	23·1	...	30·8	43	22	29	25·9	...	36·1	50	18	36	32·9	...	23·9	43	14	95	30·3	...	850
900	32·6	39	26	40	28·9	28·8	35·0	45	28	29	29·7	27·9	40·1	55	25	37	37·1	30·7	29·1	47	20	96	34·8	33·7	900
	MAY						JUNE						JULY						AUGUST						
100	−56·3	−39	−74	73	−55·2	−54·9	−49·3	−29	−63	75	−51·7	−50·9	−48·2	−37	−60	38	−51·6	−50·8	−50·2	−39	−66	26	−49·6	−52·0	100
150	−55·8	−36	−76	101	−55·5	−54·8	−48·1	−30	−73	96	−50·2	−50·5	−48·8	−35	−68	56	−52·1	−51·0	−51·7	−35	−69	53	−51·9	−53·8	150
200	−58·7	−36	−87	109	−60·1	−59·5	−49·1	−28	−74	105	−52·8	−51·7	−51·8	−30	−69	61	−53·2	−53·1	−56·5	−39	−76	66	−57·2	−57·1	200
300	−51·3	−35	−68	117	−54·5	−51·7	−47·7	−36	−58	111	−49·1	−47·0	−45·6	−30	−61	68	−45·7	−44·8	−47·9	−33	−59	81	−47·7	−45·1	300
400	−29·1	−8	−52	120	−31·3	−28·0	−24·3	−10	−42	118	−26·6	−23·9	−20·1	−2	−37	77	−19·8	−19·4	−21·8	−11	−40	87	−21·1	−18·8	400
500	−9·8	7	−37	121	−10·9	−8·0	−4·4	9	−20	118	−5·3	−3·9	0·3	11	−14	77	0·4	1·0	−1·1	10	−18	88	−0·7	1·6	500
600	4·7	20	−18	121	5·2	7·7	11·5	24	−2	118	10·7	11·6	15·3	26	1	77	16·5	16·7	14·9	25	0	88	15·2	17·3	600
700	16·8	35	−2	121	18·5	20·1	22·9	34	10	118	23·2	23·9	26·6	37	16	77	29·1	28·9	27·7	39	16	88	27·5	29·5	700
800	26·0	47	4	121	29·4	29·8	31·5	44	20	118	33·1	33·4	35·9	47	26	77	39·3	38·5	35·9	49	27	88	37·0	38·7	800
850	30·0	50	13	121	34·3	...	35·2	50	25	118	37·1	...	38·9	50	31	77	43·5	...	39·3	52	29	88	39·3	...	850
900	34·2	53	19	121	38·4	37·7	38·9	52	29	118	40·8	41·0	41·1	50	34	77	46·7	46·3	42·7	56	35	88	42·3	45·8	900
	SEPTEMBER						OCTOBER						NOVEMBER						DECEMBER						
100	−57·0	−41	−67	32	−57·9	−57·6	−64·3	−50	−75	43	−64·4	−67·9	−69·8	−52	−85	62	−76·1	−73·5	−67·0	−49	−84	47	−70·1	−75·2	100
150	−55·7	−39	−75	59	−56·7	−57·4	−62·8	−46	−79	61	−63·2	−66·7	−66·5	−50	−103	81	−74·8	−70·6	−64·1	−47	−95	77	−69·4	−72·4	150
200	−53·2	−35	−75	68	−55·7	−57·6	−63·3	−40	−86	75	−61·7	−65·9	−65·9	−44	−95	89	−73·0	−69·6	−63·9	−42	−97	93	−71·2	−73·7	200
300	−45·9	−24	−60	93	−44·5	−47·1	−52·6	−35	−75	77	−50·7	−50·7	−53·3	−27	−70	104	−54·0	−55·9	−58·3	−37	−77	104	−56·7	−59·2	300
400	−22·1	−2	−37	106	−21·8	−23·4	−30·0	−9	−49	83	−29·2	−26·0	−29·5	−3	−48	117	−28·7	−32·5	−36·3	−12	−66	114	−32·3	−35·3	400
500	−3·4	15	−18	110	−2·4	−3·8	−10·5	12	−28	83	−10·3	−5·8	−8·7	17	−30	117	−7·9	−12·3	−16·3	5	−46	114	−11·3	−14·8	500
600	10·6	30	−2	110	12·0	11·6	5·2	27	−9	83	5·3	9·7	6·9	27	−15	117	8·0	3·3	−0·1	21	−25	114	5·7	1·5	600
700	21·7	42	9	110	23·5	23·8	18·4	35	7	83	17·6	22·2	19·0	36	1	117	20·0	15·5	13·6	35	−8	114	19·2	14·6	700
800	30·5	42	21	110	32·5	33·2	27·9	47	17	83	27·1	31·3	28·1	44	12	117	28·9	25·0	23·3	46	6	114	29·5	24·7	800
850	33·4	46	24	110	36·7	...	32·0	49	21	83	30·8	...	32·1	50	18	117	32·6	...	27·7	46	13	114	32·7	...	850
900	38·9	51	28	110	41·2	41·7	36·2	54	29	83	35·6	38·4	36·0	57	26	117	36·6	33·7	33·3	49	20	114	35·9	32·5	900

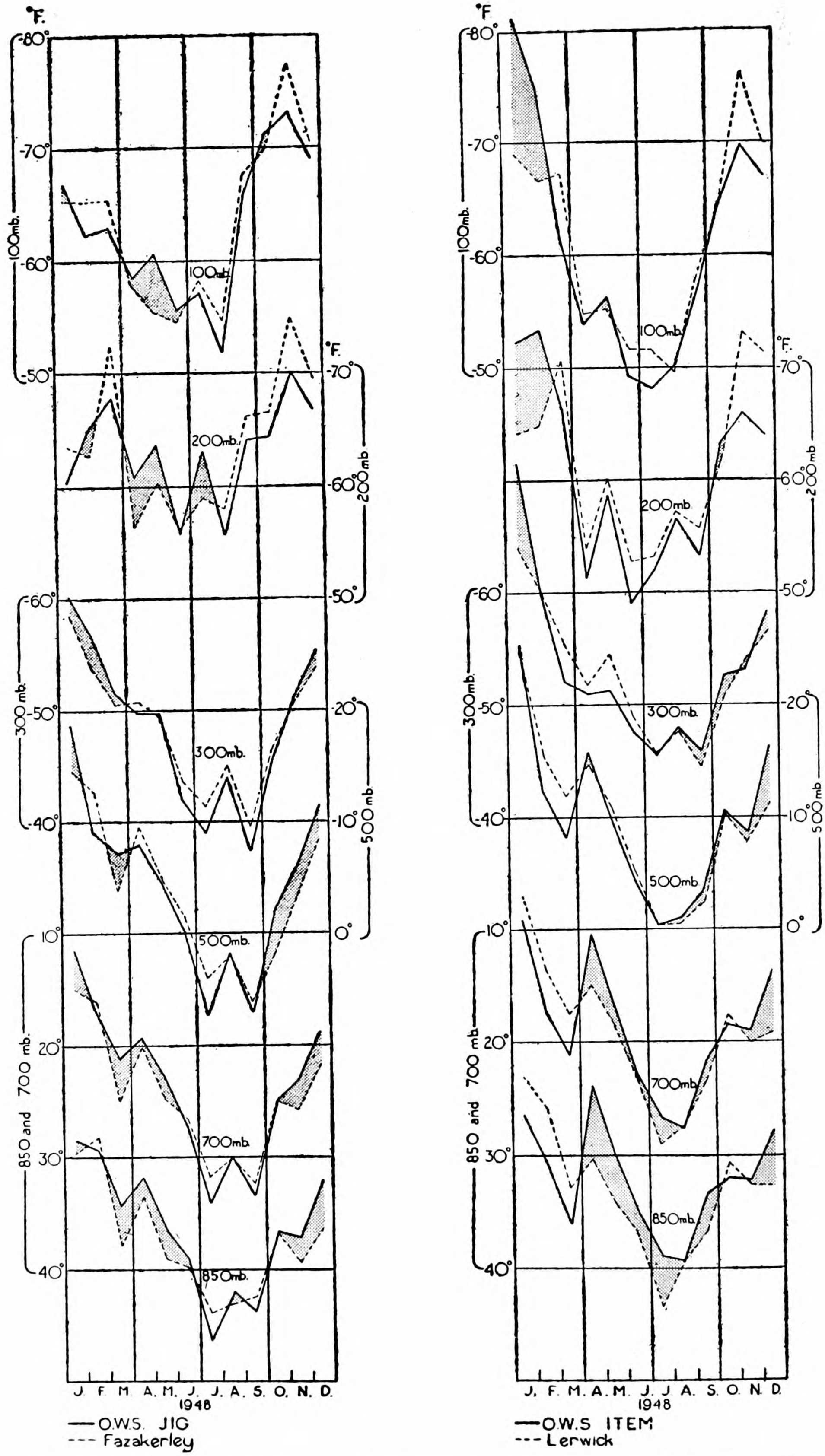

FIG. I—MEAN MONTHLY TEMPERATURES AT STANDARD PRESSURE LEVELS

nearer the main land mass while during the remainder of the year they are higher.

A limited investigation of the peculiarity shown by the JIG values was made by examining a winter month (January) and a summer month (July) in more detail. Differences between the 1400 G.M.T. temperatures for JIG and Fazakerley for individual days of each month were tabulated for those days when there were ascents at both stations. These showed that on the majority of days the sign of the difference was the same as that of the difference of the monthly means. The daily synoptic and upper air charts for each of these days were then examined to find out how these differences arose. The lower mean temperatures over JIG in January may be largely accounted for as follows. This month was comparatively mild over England, and for a considerable part of the month there was a cyclonic circulation around low-pressure systems in the central Atlantic; the air stream over Fazakerley had come from lower latitudes than that over the ship and had probably become appreciably warmer along the southerly part of its track. On the 10th and 16th the predominating effect was reversed, and temperatures were much higher over the ship (more than 20° F. higher at some levels on the 16th) but this was no doubt due to warming associated with subsidence in high-pressure ridges to the west.

The higher mean temperatures over JIG in July were found to be largely due to the persistence of an anticyclone near the ship during the first part of the month; from about 900 to 300 mb. temperatures were considerably higher (frequently 15–20° F.) in the warm subsiding air of the anticyclone. Towards the end of the month Fazakerley came under the influence of an E.–SE. air stream from the Continent while the ship was in an air stream which had come over the Atlantic. This gave higher temperatures (10–20° F.) over Fazakerley in the lower layers but above about 600 mb. the difference largely disappeared. On the 28th the air masses at the 500-mb. level over both stations seem to have been drawn from regions about 50° N., but while the air over Fazakerley had come from Poland that over the ship had come from the Atlantic; it is interesting to note that there was little difference in temperature. It seems, therefore, that 1948 was an exceptional year in this region for most of these months.

The graphs show two interesting features: unusually low troposphere temperatures over both stations in April, particularly so over ITEM, and low temperatures over JIG though not over ITEM in August.

Viewed as a whole, the curves give the impression of similarity of pattern over sea and land at the various levels up to 300 mb., roughly the level of the tropopause, where the pattern changes and is again continued upwards though the resemblance at the upper levels is more marked for ITEM than for JIG. Both stations show, in the stratosphere, a well marked minimum in November, but the minimum over ITEM in January does not occur over JIG.

Extreme temperatures for the year for the two ocean weather stations with the corresponding ranges are given in Table II. The range of temperature increases with height up to about 500 mb. and is then nearly constant up to the tropopause where there is a slight decrease followed by still larger ranges of temperature in the statosphere. In the lower troposphere the range seems to be appreciably smaller at the higher-latitude station but otherwise the range is about the same at both stations.

TABLE II —EXTREME UPPER AIR TEMPERATURES IN 1948

Pressure level	STATION JIG			STATION ITEM		
	Max.	Min.	Range	Max.	Min.	Range
mb.			*degrees Fahrenheit*			
100	−33	−94	61	−29	−91	62
150	−25	−100	75	−30	−103	73
200	−32	−103	71	−28	−97	69
300	−19	−77	58	−22	−82	60
400	8	−57	65	−2	−66	64
500	29	−36	65	17	−46	63
600	40	−18	58	30	−25	55
700	54	−1	55	42	−8	50
800	58	5	53	49	4	45
850	60	16	44	52	13	39
900	62	23	39	57	19	38

Mean lapse rates.—Mean lapse rates for winter and summer conditions were studied by plotting tephigrams of the mean monthly temperatures (mean of all four hours of observation) for January and July.

The graphs up to 300 mb. are shown in Fig. 2. The curves for January suggest that at both stations the effect of surface warming extends to about 850 mb. (4,000 ft.). Presumably this upward transfer of heat is mainly due to turbulence and it is rather surprising to find that it extends to such a height. Above 850 mb. the curves show stability increasing with height, particularly for station JIG where above 500 mb. the average lapse rate becomes appreciably less than the saturated adiabatic.

In July the curves show a decided difference in the lower layers; the curve for JIG suggests that the ocean has a slight cooling effect extending up to about 850 mb., but the curve for ITEM shows a definite warming up to 900 mb.

Other points of interest shown by the graphs are divergence between the curves for the two stations in January but parallelism in July and the appreciable difference in mean temperature between the stations. With only one year's data there is of course a possibility that these differences are due to exceptional conditions.

Diurnal variation.—Graphs were plotted for JIG, for the four hours of observation separately, for January and July, but it has not been considered worth while to reproduce them. They show, in the troposphere, a negligible variation in January and a difference of about 4° F. between the 0300 and 1500 curves in July. In the stratosphere there is a similar range both in January and July. How much of this variation is real and how much is due to insolation is a question to which it seems no satisfactory answer can at present be given.

Humidity mixing ratios.—Monthly mean humidity mixing ratios and maximum values for the year for the two ocean weather stations are given in Table III. To compare these values with those for an inland station, differences between Larkhill average monthly values for the period 1948–50 and those of Table III have been given in Table IV. Average values for Larkhill are given since means for 1948 were not readily available.

Table III shows that, apart from the winter months, the values at the higher-latitude station are appreciably less than corresponding values at the lower-latitude station.

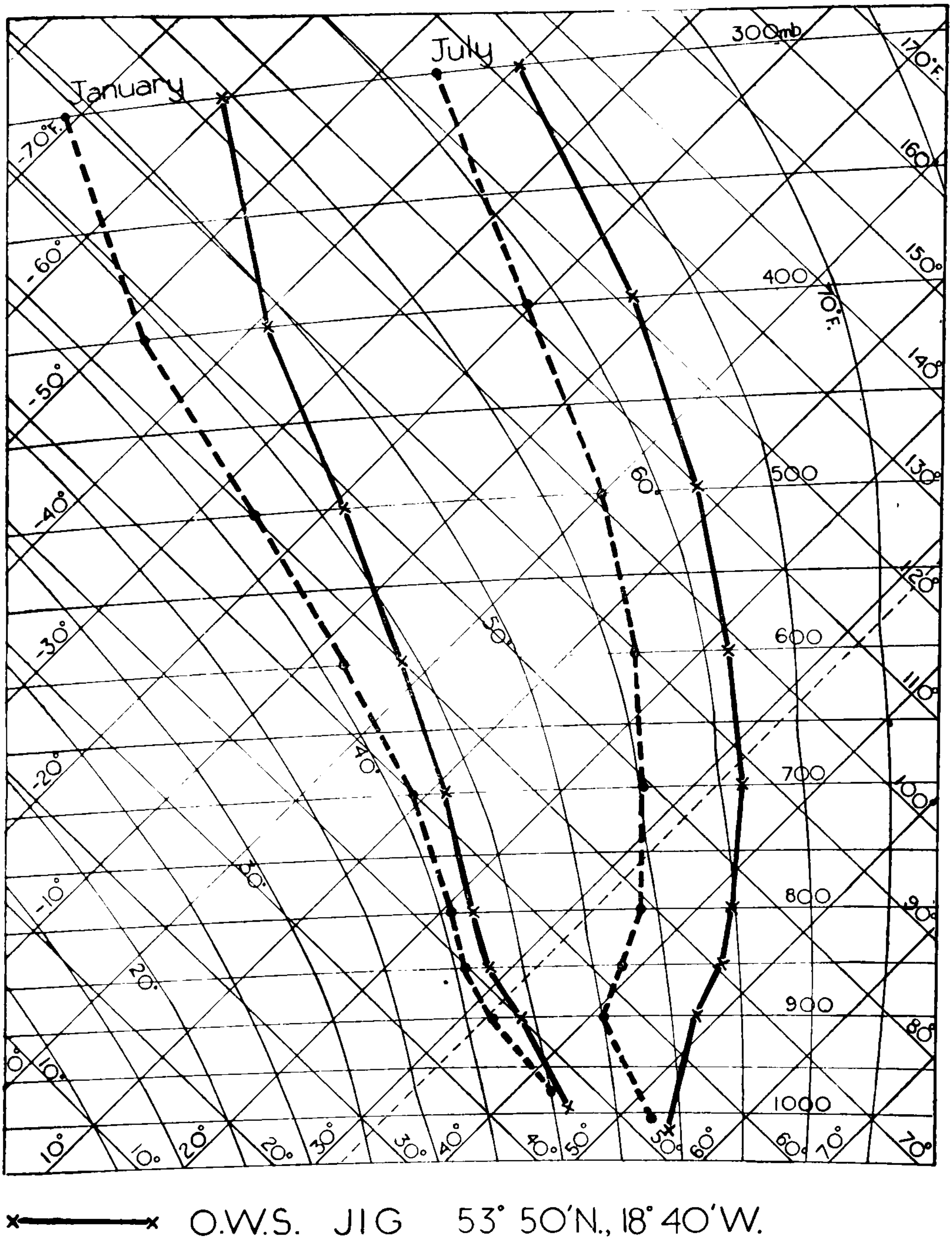

FIG. 2—MEAN MONTHLY UPPER AIR TEMPERATURES

The most remarkable feature however is how well the winter values fit the rough rule that the humidity decreases with decreasing pressure at the rate of about 0·7 gm./Kg./50 mb. from 900 to 800 mb. and about 0·5 gm./Kg./50 mb. from 800 to 700 mb. after which, from 700 to 500 mb. values at successive 100-mb. intervals are about half those at the higher pressure. In the summer months the agreement is only approximate.

TABLE III—MONTHLY MEAN HUMIDITY MIXING RATIOS AND MAXIMUM VALUES FOR 1948

Pressure level	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		YEAR
	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Max. daily value
mb.													*grams per kilogram*												
	Ocean weather station JIG (55° 50′ N., 18° 40′ W.)																								
500	0·37	82	0·48	69	0·72	98	0·71	99	0·75	114	1·01	114	1·53	112	1·17	118	1·33	111	0·82	116	0·85	111	0·55	80	5·07
600	0·75	85	0·84	70	1·42	100	1·21	99	1·37	117	1·69	114	2·53	113	2·03	120	2·23	112	1·37	116	1·51	111	0·94	80	6·68
700	1·3	87	1·6	70	2·2	101	1·8	...	2·1	119	2·7	114	3·9	114	3·1	121	3·5	114	2·2	117	2·4	111	1·6	80	9·9
800	2·3	88	2·4	70	3·4	103	2·8	100	3·2	121	4·2	115	5·4	114	4·7	121	4·9	114	3·5	117	3·8	111	2·9	80	10·8
850	3·0	88	3·1	70	4·0	103	3·4	100	3·9	121	4·9	115	6·4	115	5·6	121	5·7	114	4·5	117	4·7	111	3·6	80	12·2
900	3·7	89	3·7	70	4·7	104	4·0	100	4·7	121	5·5	115	7·0	115	6·4	121	6·4	114	5·3	117	5·5	111	4·3	80	13·0
	Ocean weather station ITEM (60° N., 20° W.)																								
500	0·31	38	0·47	29	0·63	36	0·38	96	0·57	121	0·74	115	0·94	74	0·96	85	0·77	107	0·59	80	0·71	112	0·47	111	4·23
600	0·72	39	0·94	29	1·25	36	0·73	96	1·07	121	1·43	115	1·67	74	1·71	86	1·33	110	1·10	81	1·23	113	0·89	111	5·20
700	1·3	40	1·8	29	2·1	36	1·2	96	1·7	121	2·5	117	2·8	75	2·6	86	2·1	110	1·9	81	1·9	113	1·6	112	8·2
800	2·3	40	2·6	29	3·4	35	2·0	96	2·5	121	3·7	117	4·0	76	3·8	86	3·3	110	3·1	81	2·9	113	2·7	112	8·0
850	3·1	40	3·3	29	3·9	35	2·4	95	3·1	121	4·3	117	4·7	76	4·6	86	4·0	110	3·8	81	3·5	113	3·4	112	8·8
900	3·7	40	4·0	29	4·7	36	3·0	96	3·8	121	4·9	117	5·3	76	5·4	86	4·7	110	4·5	81	4·1	114	4·0	112	10·0

TABLE IV—DIFFERENCES BETWEEN LARKHILL AVERAGES (1948–50) AND CORRESPONDING VALUES OF TABLE III

A. Larkhill values minus JIG values B. Larkhill values minus ITEM values

Pressure level	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
mb.													*grams per kilogram*											
500	0·18	0·24	0·05	0·06	−0·14	−0·05	−0·10	0·23	−0·12	0·06	−0·01	0·26	−0·42	0·17	0·06	0·27	−0·17	0·39	0·15	0·38	−0·27	−0·13	−0·02	0·06
600	0·28	0·31	0·09	−0·01	−0·37	−0·20	−0·07	0·41	−0·18	0·12	0·10	0·36	−0·60	0·26	0·14	0·46	−0·22	0·68	0·34	0·61	−0·48	−0·20	0·03	0·08
700	0·3	0·3	−0·1	−0·3	−0·5	−0·4	0·1	0·7	−0·1	0·3	0·2	0·4	−0·8	0·3	0·3	0·8	−0·3	1·1	0·4	0·7	−0·7	−0·2	−0·1	−0·1
800	0·3	0·3	0·0	−0·2	−0·8	−0·8	0·2	1·0	−0·1	0·6	0·2	0·7	−0·6	0·8	0·4	1·3	−0·1	1·5	0·3	0·7	−1·0	−0·1	−0·5	−0·3
850	0·3	0·2	−0·1	−0·3	−0·9	−0·8	0·1	1·1	0·1	0·9	0·5	1·1	−0·4	1·3	0·4	1·4	0·0	1·7	−0·1	0·6	−1·2	0·0	−0·6	−0·4
900	0·3	0·3	−0·1	−0·4	−0·9	−0·9	0·2	1·2	0·1	1·0	0·9	1·5	−0·1	1·6	0·6	1·6	0·4	2·1	0·0	0·8	−1·3	0·1	−0·6	−0·3

Values have only been given up to 500 mb. in the above tables. Humidity observations are regarded as completely unreliable for temperatures below −40° F. and omission of values for observations when temperature was below −40° F. gives biased means for 400 and 300 mb.

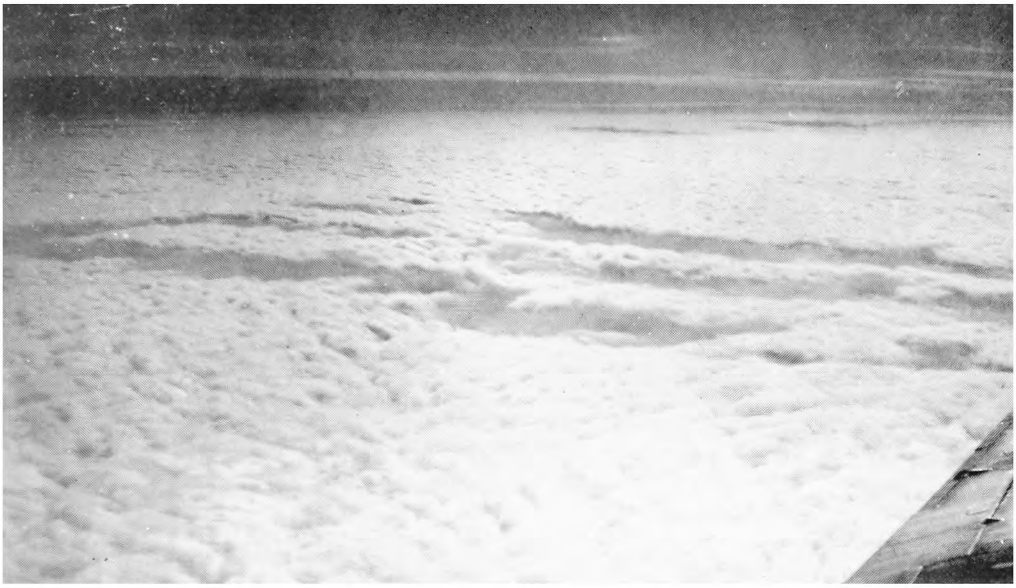

FIG. 1—VIEW OF SEEDED AREA FROM 20,000 FT., 17 MINUTES AFTER COMPLETION OF SEEDING

(see p. 253)

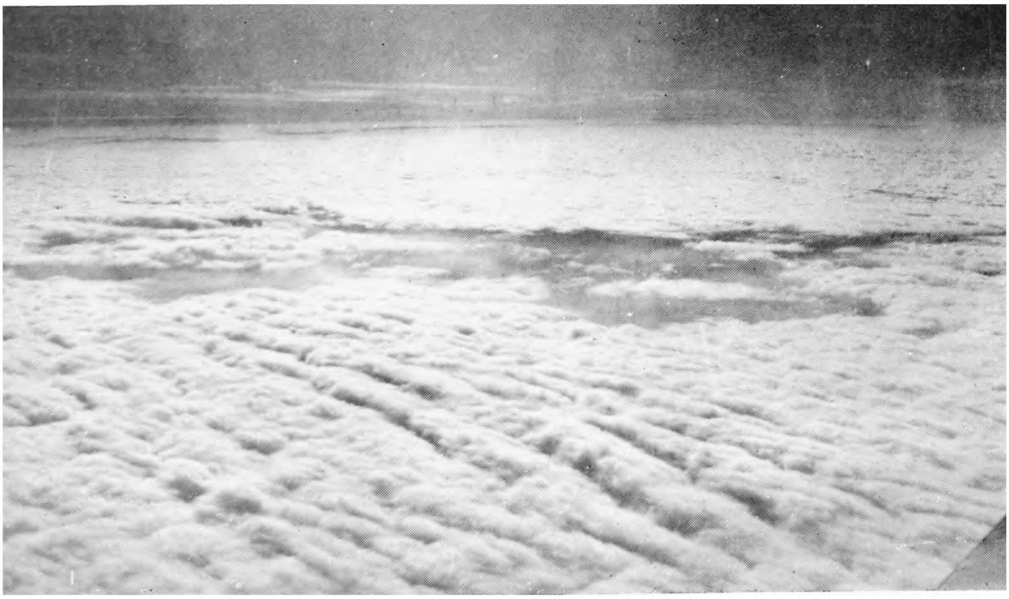

FIG. 2—VIEW FROM 20,000 FT., 40 MINUTES AFTER COMPLETION OF SEEDING

(see p. 253)

To face p. 253]

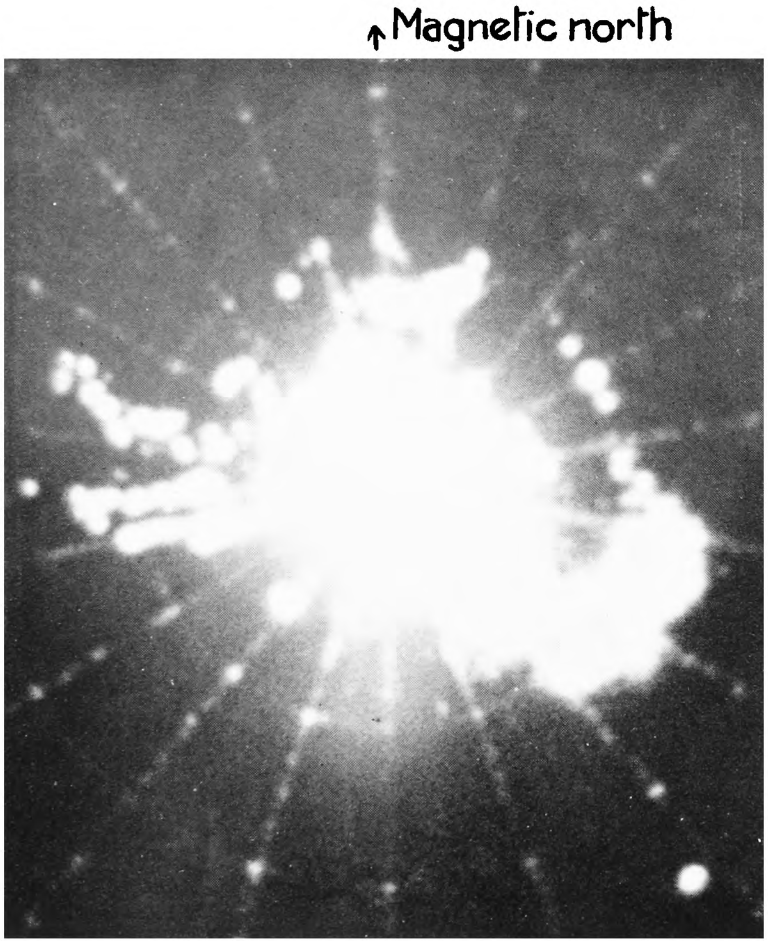
↑ Magnetic north

FIG. 3—PHOTOGRAPH OF P.P.I. AT EAST HILL SHOWING ECHO PRODUCED BY FIRST SEEDED LANE, 15 MINUTES AFTER COMPLETION OF SEEDING

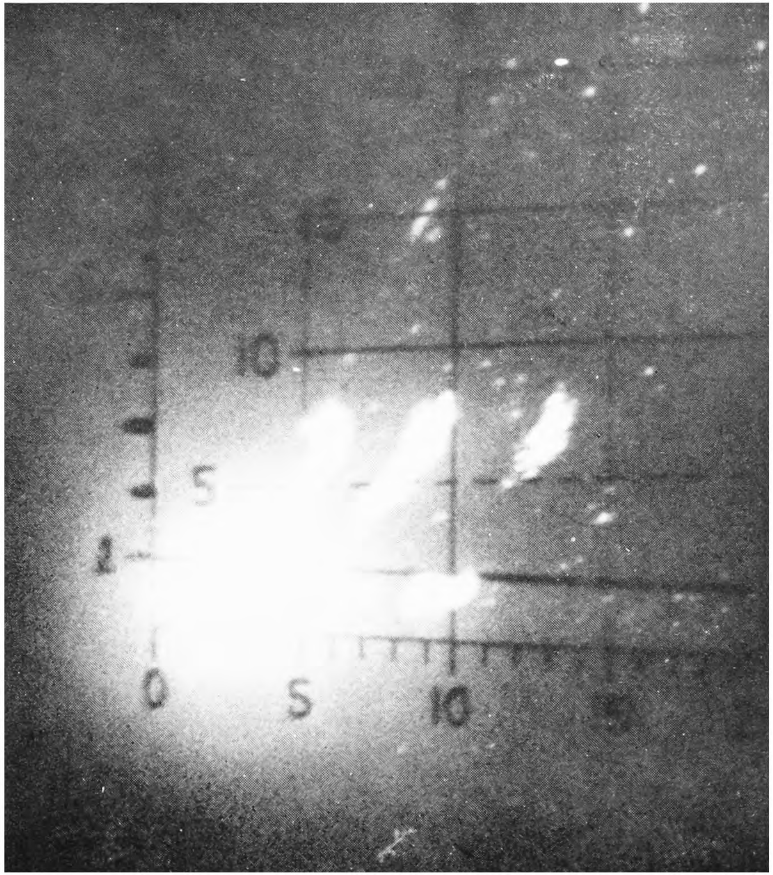
0
5
10
15
5
10
15

FIG. 4—PHOTOGRAPH OF H.R.T. AT EAST HILL SHOWING ECHOES PRODUCED BY ALL THREE SEEDED LANES, 26 MINUTES AFTER COMPLETION OF SEEDING

The figures of Table IV show that, with the exception of November, there is little difference between JIG and Larkhill, and that from April to October the humidity over ITEM is appreciably less than that over Larkhill though during the months November to February the difference is negligible. From these figures, based on data for one year only, it would seem that the nature of the underlying surface has little effect on the upper air absolute humidity and that latitude is the most important factor.

Tropopause.—Monthly mean values of pressure and temperature at the tropopause for all hours of observation are given in Table V. Very little can be deduced from the values. The usual relation of low pressure and low temperature between tropopause pressure and temperature is shown for most months, but from October to December, though the tropopause pressure increases, the temperature is nearly constant. The pressure curves for both stations are generally similar but that for JIG shows greater fluctuations. In every month except January and February the mean tropopause level is lower at ITEM than at JIG.

TABLE V—MONTHLY MEAN VALUES OF TROPOPAUSE PRESSURE AND TEMPERATURE AT ALL HOURS OF OBSERVATION

	Station JIG			Station ITEM		
	Pressure	Temperature	No. of obs.	Pressure	Temperature	No. of obs.
	mb.	°F.		mb.	°F.	
January	295	−67	55	283	−75	39
February	251	−69	43	251	−75	21
March	235	−71	72	243	−70	31
April	253	−64	81	295	−57	71
May...	239	−68	101	263	−64	110
June...	249	−61	86	265	−58	107
July	213	−68	95	247	−61	63
August	242	−61	108	247	−64	75
September	203	−70	100	265	−58	77
October	217	−71	90	252	−67	68
November	237	−72	95	251	−70	94
December	257	−71	77	269	−70	93
Year...	241	−68	1,003	261	−66	845

The rather erratic values in Table V may be due mainly to the difficulty of identifying the position of the tropopause with any accuracy, and it seems that a much longer period of observations will be required before any significant features can be picked out. It would have been interesting to compare mean monthly tropopause heights at Fazakerley and JIG but data were not readily available.

Upper winds.—No data are given for upper winds in this note as values for both stations are being prepared for publication in *Monthly Frequency Tables.*

RESULTS OF AN ARTIFICIAL NUCLEATION EXPERIMENT

By H. C. SHELLARD, B.Sc. and D. R. GRANT, B.Sc.

Introduction.—On the afternoon of March 9, 1951, a cloud-seeding experiment was carried out from a Hastings aircraft of the Meteorological Research Flight. The cloud chosen was a well defined layer of stratocumulus, base 9,000 ft., top 9,500 ft., with a temperature at its top of +15°F. Below this cloud was a layer of thick stratocumulus from about 1,000 to 7,000 ft., with some patchy cloud between the two layers. Winds taken from the Downham Market radio-sonde ascent for 1400 G.M.T. were 050° 25 kt. at 2,000 ft. veering and decreasing with height to about 090° 10 kt. at 9,500 ft. Seeding commenced just after 1400 G.M.T., at 9,500 ft. and at a point about 080° 15 miles from the Meteorological Office radar station at East Hill. Dry-ice pellets ½–1 cm. in diameter were dropped at a rate of about 1lb./mile; and an S-shaped track, in which the legs (orientated 330–150°) were initially about 10 miles long and 2½ miles apart, was flown. Total seeding time was 11 min.

Visual observations.—The usual effects on the cloud top were noticeable as soon as sufficient height had been gained to see them clearly. The most interesting features were the rates of spread and changes in shape of the seeded lanes. Some 8–10 min. after completion of seeding the effect of a horizontal wind shear approximately at right angles to the lanes was clearly visible. The rate of spread of the lanes was greatest in the region of shear, and, from photographs taken, was deduced as being about 4 m.p.h. there and about 2 m.p.h. elsewhere. As in the experiment* of January 25, 1950, the change in wind took place over a very short distance, which unfortunately cannot be determined from the photographs. Fig. 1, taken from 20,000 ft. 17 min. after seeding in direction 210°, shows the three lanes beginning to join up near the shear line. There is also evidence of some vertical development in the form of cumulus heads just to one side of the line.

Fig. 2 is another view from the north-west taken 40 min. after completion of seeding. The separate lanes were now barely distinguishable and the cloud was completely cleared near the centre of the area.

Radar observations.—During the experiment frequent photographs were taken of the radar echoes obtained from the area on P.P.I. and H.R.T. indicators at East Hill. The first sign of echo appeared about 11 min. after completion of seeding. Fig. 3, a P.P.I. photograph taken 15 min. after seeding, shows an echo extending in a direction 150–330° from a position 100°, range 11 miles, to a position 040°, range 10 miles, from East Hill. This is certainly the first seeded lane and the horizontal wind shear already mentioned is visible at a bearing 080° from East Hill. Later photographs showed this echo drifting towards East Hill until by 1437 it was almost lost in the permanent echoes. It is difficult to explain why no well marked echoes appeared from the other two seeded lanes because as far as possible the rate of seeding was kept constant.

The H.R.T. photographs showed echoes from all three seeded lanes though that from the first was much the most intense. Fig. 4, a good example, was taken 26 min. after completion of seeding. Unless the rate of seeding is completely uniform the H.R.T. will show more pronounced echoes than the P.P.I. because the former is operated on the most favourable azimuth. The H.R.T. photographs also reveal the wind shear in the vertical and, using the Downham Market radio-sonde winds for 1400 G.M.T., the rate of descent of the snow (assumed constant) may be calculated. It was found to be 4·2 ft./sec. in the first lane. Comparison of the shapes of the three columns in Fig.4 shows the rate of fall to be less in the second and third lanes, indicating that the ice crystals were smaller and suggesting that these lanes were overseeded, resulting in many more, and therefore smaller, ice crystals. It seems that the results obtained depend

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*FRITH, R.; Wind shear revealed by artificial nucleation. *Quart. J. R. met. Soc., London,* 77, 1951, p. 131.

very critically on the seeding rate. On the H.R.T. photographs there are a few echoes with tops at 2,000–3,000 ft. which were possibly produced by seeding of the lower layer, but this is unlikely as some echoes were present at this height before seeding.

At about 1440 G.M.T. precipitation from the first seeded lane was observed falling to the gound at East Hill. It was of an entirely different nature from the intermittent frozen drizzle which had been falling previously, being quite definitely snow although not in very large flakes.

By about 1500 G.M.T. all the radar echoes had disappeared and the aircraft descended through the gap in the clouds. There were still some *virga* in the vicinity and the optical effects showed that ice crystals were still present in parts of the seeded area.

We are indebted to Mr. R. F. Jones for providing the radar photographs and the ground observations from East Hill.

FOG AT NORTHOLT AIRPORT

By W. E. SAUNDERS, B.Sc. and W. D. SUMMERSBY, B.Sc.

It has been suggested that an analysis of fog at Northolt Airport on similar lines to that recently published by N. E. Davis[1] in regard to London Airport might be of interest to airline operators and to forecasters.

Northolt is six miles north-north-east of London Airport and is 120 ft. above M.S.L. compared with the 82 ft. of London Airport.

In this note, to facilitate comparison, the same four-year period (August 1946–July 1950) has been covered, and the same visibility limits have been used (visibility $\leqslant$220 yd., $\leqslant$440 yd., $\leqslant$880 yd., and $\leqslant$1,100 yd.). Thick fog has been regarded as visibility $\leqslant$220 yd.

The diurnal variation of fog within these ranges is given in Table I, and the percentage frequencies of fog and thick fog in Fig. 1 and Fig. 2 respectively.

The most significant features appear to be as follows:—

(i) The minimum frequency of fog in July.

(ii) The gradually increasing fog frequency in August and September, mainly forming after midnight and clearing at 0600–0900.

(iii) The rapid increase in fog frequency in October, and the tendency to clearance at 0900–1200. But towards the end of the month occasional all-day fogs are experienced.

(iv) The further increase in frequency in November, with marked tendency for the fog to persist all day.

(v) The rapid decrease in frequency from November to December, and the gradual decrease from December to March.

(vi) The relatively low frequency at 0600–0700 in December and January, and December the only month of the year in which the evening maximum fog frequency exceeds the morning maximum.

(vii) The gradually increasing tendency for fog to clear during the forenoon from January to March.

(viii) The rapid decrease in frequency from March to April, and the gradual decrease from April to July.

These features may be explained from a consideration of the nature of the fog at various seasons.

TABLE I—DIURNAL VARIATION OF FOG AT NORTHOLT AIRPORT

Summer months

Time	APRIL				MAY				JUNE				JULY				AUGUST				SEPTEMBER			
	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.
G.M.T.	*number of occasions in four years*																							
0000	...	...	...	1	...	...	...	...	...	2	2	3	...	...	...	...	...	...	...	1	...	1	1	1
0100	...	...	...	...	1	1	2	4	1	1	2	2	...	...	...	...	...	...	1	1	...	1	3	4
0200	...	...	...	...	1	2	4	5	1	1	3	4	...	...	...	1	...	2	5	5	3	5	6	7
0300	...	...	...	1	1	1	4	5	1	2	4	5	...	...	1	2	3	3	6	6	3	5	6	8
0400	...	1	1	2	2	2	4	5	2	2	3	4	...	...	1	1	4	4	6	7	5	8	10	11
0500	1	3	5	7	4	5	7	8	3	3	4	5	1	1	1	2	6	9	9	12	5	7	13	14
0600	1	2	4	9	3	5	6	8	1	1	1	2	...	2	2	2	8	10	11	11	7	7	16	19
0700	1	2	3	7	1	3	3	5	1	1	1	1	...	...	...	...	1	2	6	6	3	4	6	10
0800	1	1	4	6	...	...	...	2	...	1	1	1	...	...	...	...	1	1	1	2	3	3	6	7
0900	...	...	...	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	1	2
1000	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1100	...	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1200	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1300	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
1400	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
1500	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1600	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1700	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1800	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
1900	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
2000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
2100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1
2200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1
2300	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	1	1
Total	4	9	21	53	13	19	31	43	10	14	22	29	1	3	5	8	23	31	45	53	30	42	70	91
Mean (hr./month)	1	2	5	13	3	5	8	11	3	3	5	7	0	1	1	2	6	8	11	13	7	11	17	23

Winter months

TABLE I—*continued*

Time	OCTOBER				NOVEMBER				DECEMBER				JANUARY				FEBRUARY				MARCH			
	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.
G.M.T.	*number of occasions in four years*																							
0000	8	13	21	23	14	16	25	27	8	11	16	19	4	8	13	15	4	5	11	15	5	6	11	17
0100	11	13	18	26	13	17	22	24	10	11	14	18	3	8	10	16	4	5	10	15	6	7	13	17
0200	9	12	20	24	12	17	22	25	9	9	12	15	6	7	10	12	5	6	11	15	4	5	8	14
0300	10	17	24	26	16	20	20	27	8	10	12	15	4	7	10	13	4	7	12	16	6	6	8	14
0400	12	12	19	25	14	18	19	24	7	8	10	13	3	7	8	12	3	4	10	15	5	5	7	13
0500	11	12	20	25	15	18	22	24	6	7	8	14	4	6	8	9	4	5	11	15	5	6	8	13
0600	15	17	22	26	14	20	26	29	5	5	6	9	4	7	9	10	4	5	8	14	6	7	11	16
0700	13	15	24	30	15	21	28	31	5	6	6	7	5	8	9	9	4	5	12	16	9	10	19	23
0800	9	13	23	27	22	23	31	33	5	5	9	14	8	10	13	17	5	8	19	20	8	11	16	21
0900	8	11	21	25	18	23	28	32	5	7	12	17	7	12	15	22	7	9	18	24	8	11	18	20
1000	6	9	15	20	15	19	30	35	5	7	15	19	7	11	16	25	7	8	14	22	4	4	11	14
1100	...	5	9	13	11	14	23	27	6	7	12	18	7	10	13	23	2	5	12	14	3	4	8	11
1200	...	1	4	11	9	10	18	23	5	7	12	17	6	8	11	19	2	3	8	14	...	2	5	9
1300	...	...	2	5	8	11	14	19	5	7	9	15	5	6	10	13	3	3	7	9	...	1	4	5
1400	...	1	2	3	6	7	13	18	6	6	11	15	1	1	6	8	2	3	6	9	...	2	3	3
1500	...	1	2	3	7	8	13	18	6	6	12	15	...	1	6	11	2	4	8	9	1	2	3	4
1600	...	...	2	3	8	10	14	18	5	8	14	18	...	...	11	16	2	3	4	6	1	2	3	4
1700	...	1	3	7	8	10	17	24	6	8	11	20	...	3	12	19	1	2	5	8	1	2	4	9
1800	1	2	6	15	7	10	14	20	7	8	14	19	1	4	9	14	2	2	7	12	1	2	5	10
1900	1	1	5	11	9	11	14	23	6	11	11	20	1	4	10	14	1	4	9	13	2	4	8	13
2000	1	2	10	15	10	13	17	23	8	9	14	19	1	4	12	20	4	4	10	12	3	6	8	14
2100	...	2	9	20	13	15	19	24	8	11	13	22	3	6	11	20	4	6	12	15	3	6	8	12
2200	...	3	11	17	13	15	21	23	8	10	14	19	3	5	12	17	5	8	11	14	4	5	10	14
2300	5	8	16	20	15	17	25	26	7	9	14	17	5	8	14	17	5	6	10	15	3	5	7	11
Total	120	171	308	420	292	363	495	597	156	193	281	394	88	151	258	371	86	120	245	337	88	121	206	301
Mean (hr./month)	30	43	77	107	73	91	124	149	39	48	70	99	22	38	65	93	21	30	61	84	22	40	51	75

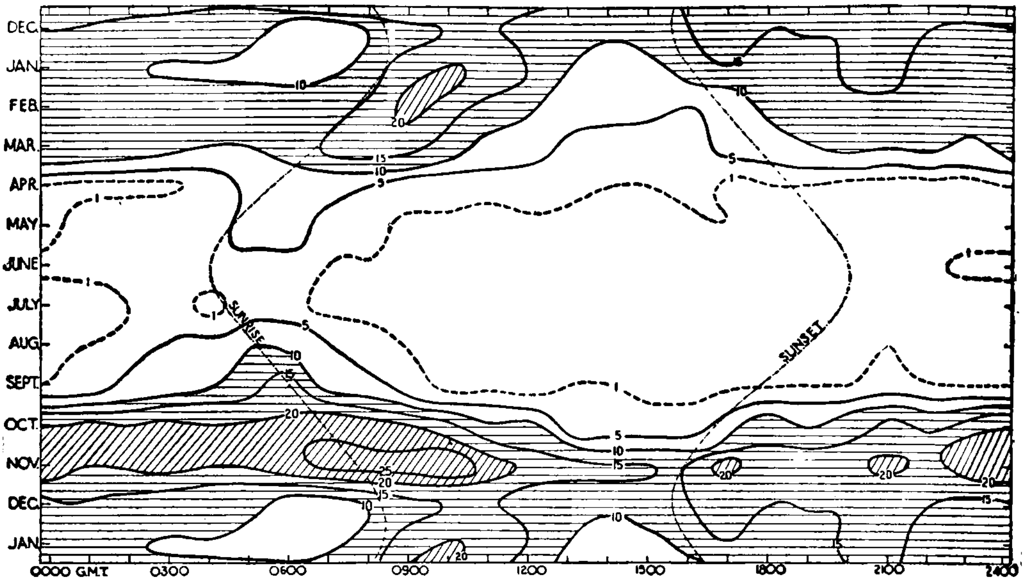

FIG. 1—DIURNAL VARIATION OF FOG AT NORTHOLT AIRPORT

Fog at Northolt is mainly a combination of radiation and smoke fog. Advection fog is very rare, probably occurring on an average less than once a year.

In the summer half year fogs are almost exclusively water fogs. The screen-level temperature at which water fog forms (the fog point) has recently been investigated by Saunders[2]. This temperature has been shown to be conservative within a degree or so at airfields which include Northolt and London Airport. It is approximately proportional to the hydrolapse and to the depression of screen-level dew point below dry-bulb temperature at the time of maximum temperature. In summer and early autumn the fog point is relatively high, mainly within the range of 40–60°F. The gradually increasing fog frequency during this season reflects the greater tendency for the fog point to be reached with the increasing length of night.

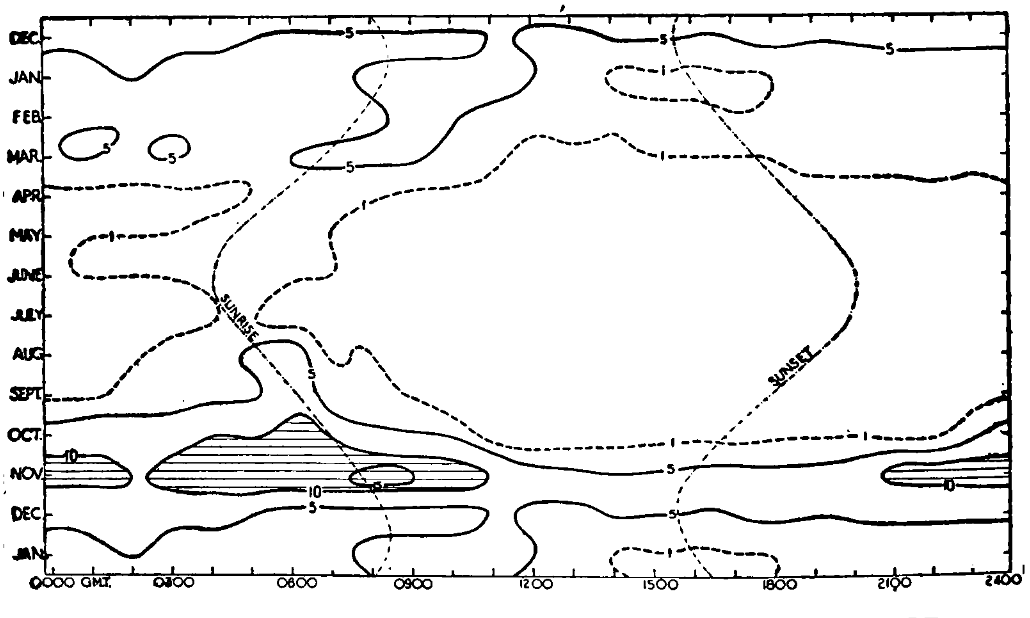

FIG. 2—DIURNAL VARIATION OF THICK FOG AT NORTHOLT AIRPORT

From October smoke becomes significant. Northolt is materially affected by London smoke (a combination of domestic and industrial smoke) when the surface wind is between NE. and SSE., and by domestic smoke from various local sources. It is important to recognize that London smoke will reduce visibility into the fog range with low relative humidity, if other conditions are favourable. Thus occasions have been known with visibility at Northolt below 200 yd. with relative humidity 60–70 per cent., e.g. February 6, 1949, 1600 G.M.T., visibility 180 yd., relative humidity 70 per cent. The local smoke sources are also occasionally sufficient to produce dry fog at Northolt. It follows that water fog and smoke fog must be considered separately until the relative humidity reaches the range 90–100 per cent.

The extent to which the smoke affects visibility at Northolt will depend upon:—

(i) Season of year.
(ii) Time of day.
(iii) Day of week.
(iv) Temperature lapse rate.
(v) Surface wind direction.
(vi) Surface wind speed.

During the summer half year domestic smoke is negligibly slight. Industrial smoke continues, but only very rarely reduces visibility into the fog range. During the winter half year, as Davis points out, domestic fires are burning from 0700–0800 to about 2200 during November to March, and during evenings in October and April. On Sundays and public holidays most fires are lighted later in the mornings, and there is little industrial smoke. For the smoke by itself to reduce visibility into the fog range it must be concentrated beneath a low temperature inversion near the ground. A suitable inversion will develop due to ground cooling on any evening when there is clear sky and light wind. During summer the inversion will break down rapidly after sunrise, but during winter it will remain most of the day, often all day. It follows from these considerations that there is a smoke maximum at 0800–1000 on weekdays, and it has been noted on many occasions that this is delayed until 1100 on Sundays. There is a secondary smoke maximum towards dusk due to the formation or intensification of the ground inversion at this time, accentuated in October and April by smoke from freshly lighted fires. There is a smoke minimum at about 0600 due to smoke having been gradually deposited or carried away during the night. There is a secondary smoke minimum in the early afternoon, when the inversion is most likely to break down, if at all.

The effect of increasing wind speed, at any time, is that the base of the inversion is raised above the ground, and the smoke or fog is distributed through a greater depth. Accordingly, we find that water fog is usually dispersed when the wind speed reaches a critical value in the region of 5–7 kt., and that only the worst cases of smoke fog continue when the wind speed exceeds 10 kt.

In November south-east England is still mainly under the influence of air streams of maritime origin. The water-fog point is still relatively high, mostly in the range 35–45°F. In addition the night is longer and smoke output at the winter level. Hence the November maximum fog frequency for the year. The chance of fog clearing during the day is much decreased by the reduced insolation.

The significant change in December is that south-east England tends to have appreciably drier air of continental origin. Davis has expressed this change in terms of the mean vapour pressure. In terms of the water-fog point it means, on the average, a reduction to the range 25–35°F. with a corresponding decrease in moisture content. On a rural non-smoky site fog will not in general form when the calculated fog point is reached, when this is below 32°F. Hoar-frost or rime will form instead of fog. At Northolt in these circumstances the question whether fog will form will usually depend upon the smoke situation at the time the calculated fog point is reached. The December fog minimum at 0600–0700 is therefore readily explicable from the smoke minimum at this time together with the low water-fog points usually experienced.

During January to March smoke fog continues to predominate. Increased day heating leads to the increasing number of fogs which clear in the forenoon, and all-day fogs are rare by March.

Comparison of the total number of occasions of fog in all the hourly reports shows that the difference between Northolt and London Airport is negligibly small—Northolt had 5 hr. more " fog " and 1 hr. more " thick fog " than London in 4 years. A more detailed comparison is given in Fig. 3 and Table II.

TABLE II—MONTHLY VARIATION IN THE TIME OF MORNING MAXIMUM FOG FREQUENCY AT NORTHOLT AND LONDON AIRPORT

Month	Time of morning maximum		Month	Time of morning maximum	
	London	Northolt		London	Northolt
January	0900	1000	July	0400	0300
February	0900	0900	August	0600	0500
March	0800	0700	September	0600	0600
April	0600	0600	October	0800	0700
May	0500	0500	November	0900	1000
June	0600	0500	December	1000	1000

Fig. 3 shows that there is more fog at Northolt in seasons when water fog predominates, and more at London Airport when smoke fog is common. Table II shows that during the water-fog period the time of fog formation is, on the average, up to 1 hr. earlier at Northolt, while in the late winter months this tendency is to some extent reversed.

These circumstances may readily be explained in terms of the nocturnal cooling, the water-fog point, and the surface wind direction. Owing to differences in soil* between the two airfields early evening cooling is more rapid at Northolt, where it has been noted that the evening temperature discontinuity[3], which is now believed to mark the commencement of dew or hoar-frost formation, is reached up to 1 hr. earlier than at London Airport. This difference is carried forward during the subsequent cooling. It follows that the water-fog point is reached up to 1 hr. earlier at Northolt, and that on some occasions it is just reached at Northolt but not at London Airport. The excess of fog at London Airport during January to March may partly be attributed to the tendency, shown in the wind rose for Greenwich[4], for increasing frequencies of NE. and decreasing frequencies of SE. winds at this season, resulting in rather more London smoke being carried to London Airport than to Northolt.

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*Soil types:—*London Airport:* 6–9 in. vegetable soil, then Taplow brick earth down to 3 ft., then gravel down to 10–15 ft. and below that London clay.

Northolt: very little top soil at all, heavy clay from near the surface downwards, no gravel layer.

The general conclusions, as affecting airline operators, are similar to those expressed in Davis' final paragraph, with the addition that during late summer and early autumn London Airport will often be suitable for diversion of aircraft at the time morning fog is forming at Northolt.

The similarity between the two airfields suggests it might be worth obtaining similar figures for an airfield on the opposite side of London. This would show to what extent the greater tendency for instability in N.–WNW. air streams decreases the fog frequency, and might lead to the general conclusion that from this point of view airports should preferably be sited to the south or south-east of large towns.

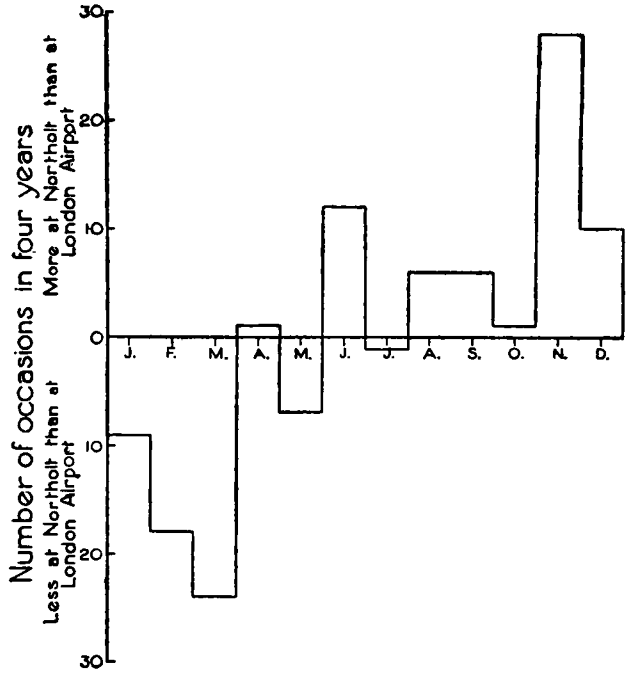

FIG. 3—MONTHLY VARIATION IN THE FREQUENCY OF FOG BETWEEN NORTHOLT AND LONDON AIRPORT

Mr. N. E. Davis comments as follows on the monthly differences between the number of hours of " thick fog " at Northolt and London Airport.

" An even more remarkable result is that the number of hours of ' thick fog ' at London Airport minus the number of hours at Northolt is only 1 hr. over the period of four years. The individual monthly totals vary from 266 hr. thick fog at London Airport and 299 hr. at Northolt in November to 139 hr. at London Airport and 88 hr. at Northolt in January. These figures bear out the statement that Northolt is more subject to water fogs and London Airport to smoke. In January Northolt with a low fog point has less thick fog, the excess moisture being deposited as hoar-frost, but at London Airport, with a greater amount of smoke, excess moisture is deposited on the smoke particles resulting in a thick fog."

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SEVERE TURBULENCE ENCOUNTERED BY AIRCRAFT NEAR JET STREAMS

By J. K. BANNON, B.A.

Introduction.—It is well known that atmospheric turbulence can occasionally have a noticeable effect on the flight of an aircraft even in the cloudless air usually found at high altitudes. The resulting irregular accelerations or " bumps " are usually slight but exceptionally they may be sufficiently developed to be described as severe. Though bumps have been observed between the levels of 20,000 and 40,000 ft. in many varied meteorological situations in temperate latitudes, the neighbourhood of the fast-moving streams of air known as jet streams appears to be favourable for the occurrence of turbulence at high altitude[1]. This note discusses three occasions of jet streams in the upper troposphere when aircraft experienced severe turbulence at heights above 28,000 ft.

Turbulence incidents.—Details of time, place and altitude of the incidents of severe turbulence are given in Table I and also the type of aircraft in which the bumps were experienced.

TABLE I—OCCASIONS OF SEVERE TURBULENCE NEAR JET STREAMS

Incident	Date	Time	Place	Height*	Aircraft
		G.M.T.		ft.	
A_1	14.11.49	1130	York to Durham	35,000	Comet
A_2	14.11.49	1300	Orkneys	35,000–38,000	Comet
A_3	14.11.49	1530	Just east of Felixstowe	35,000–36,000 32,000	Comet Venom
B	2.11.50	1250	Flushing (Holland)	35,000	Comet
C_1	7.11.50	1400	Leicester	28,000–32,000 39,000–41,000	Meteor
C_2	7.11.50	1430	Cromer to Skegness	33,000–38,000	American F.86, Meteor and others
C_3	7.11.50	1345 1500	West Raynham Spalding	28,000–34,000 29,000–31,000†	

* As measured with an I.C.A.N. altimeter. † Maximum intensity.

The case of November 14, 1949, has been described in detail by Hislop[2]; on a long flight by a Comet aircraft, roughly along the track of a well marked jet stream, turbulence of unusual intensity was experienced in several places. A visual accelerometer was fitted in the cockpit of the aircraft but the indications of this instrument are not considered to give a reliable measure of the accelerations experienced at the centre of gravity of the aircraft; however, Hislop[3] has estimated that the maximum equivalent gust velocity* experienced in the York–Durham area (incident A_1, Table I) was about 35 ft./sec. which is comparable with gusts met in cumulonimbus clouds. The turbulence in incidents A_2 and A_3, though giving bumps which most pilots would assess as severe, were much less severe than the exceptional gustiness of incident A_1.

From the readings of the visual accelerometer it is estimated that the equivalent gust velocities experienced on November 2, 1950, (incident B) were about 20 ft./sec. or a little less.

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*The equivalent gust velocity[4] is a useful parameter of gustiness as affecting aircraft; it is a calculated equivalent velocity which, if the gust were vertical, of unlimited horizontal extent and built up linearly in a distance of 100 ft., would produce the acceleration experienced by the given aircraft at the same equivalent forward speed.

In the incidents reported on November 7, 1950, the assessments of gustiness were purely qualitative but were variously noted as severe, or violent or very considerable.

Meteorological situation.—Figs. 1, 2 and 3 show diagrammatic synoptic charts for sea level for the three days of severe gustiness, November 14, 1949, November 2 and 7, 1950, respectively. The weather situations at sea level do not seem to have many points in common. In each case, however, a comparatively narrow zone of fast-moving air or jet stream was present in the upper troposphere in the region where the turbulence was found. (For a description and discussion of jet streams see a paper by Durst and Davis[5].) The axes of these jet streams are indicated in Figs. 1, 2 and 3 and details of some of the characteristics of these jet streams are given in Table II.

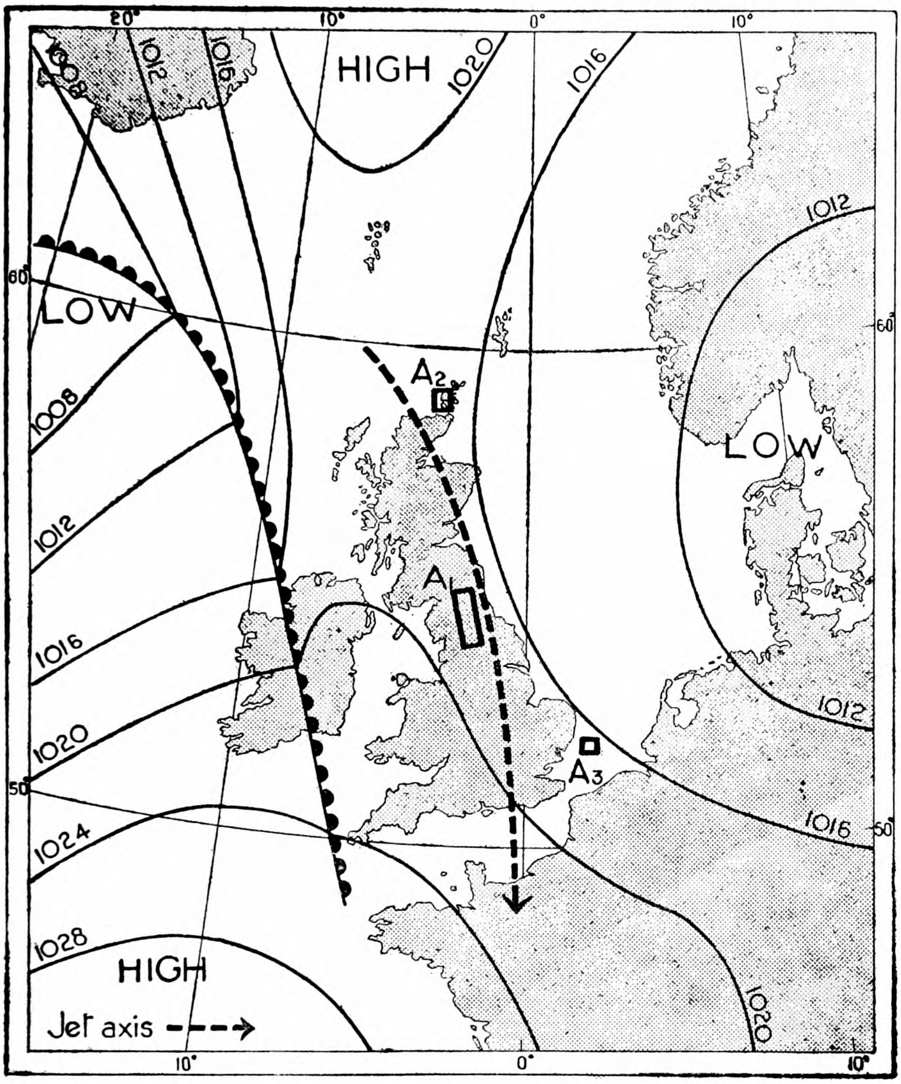
20°
10°
0°
10°
1008
1012
1016
HIGH
1020
1016
60
LOW
A2
1008
1012
A1
1016
1020
A3
50
1024
1028
HIGH
Jet axis
1012
60
LOW
1012
1016
50
1020
10°
0°
10°

FIG. 1—SYNOPTIC CHART, 1200 G.M.T., NOVEMBER 14, 1949 SHOWING THE REGIONS OF OBSERVED TURBULENCE

The nature of a jet stream is best understood by considering a vertical cross-section at right angles to the general air stream; many examples of cross-sections of jet streams have been published, e.g. by Durst and Davis[5] or by the

University of Chicago[6], and cross-sections of the three cases considered here did not show any unusual features and were in many ways very similar.

To get an idea of which parts of a jet stream are liable to severe turbulence, data for the three occasions were averaged to give a mean cross-section which is

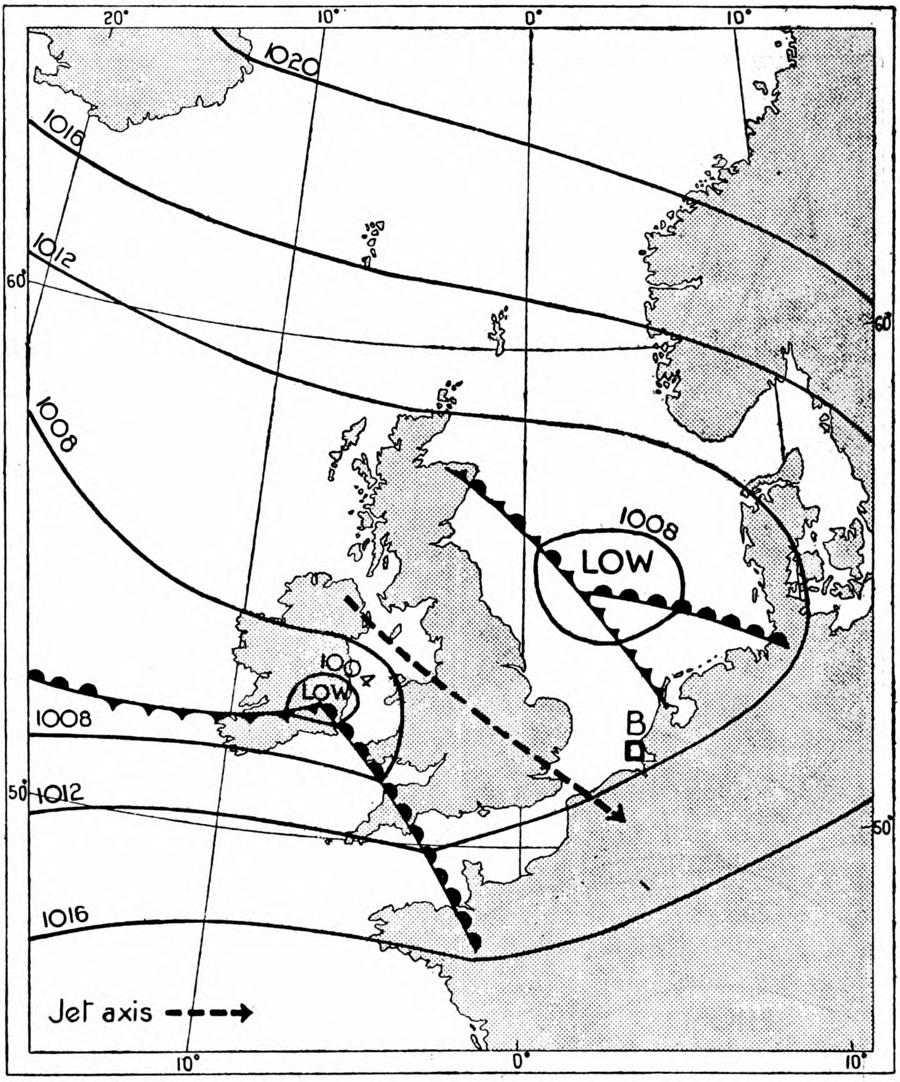

FIG. 2—SYNOPTIC CHART, 1200 G.M.T., NOVEMBER 2, 1950 SHOWING THE REGIONS OF OBSERVED TURBULENCE

TABLE II—CHARACTERISTICS OF THREE JET-STREAM CROSS-SECTIONS

Date	Height* of jet axis	Pressure of jet axis, P_J	Maximum wind speed	Scale of horizontal units in Fig. 4†
	ft.	mb.	kt.	nautical miles
14.11.49	31,600	280	160	113
2.11.50	29,000	315	140	54
7.11.50	32,700	265	130	151
Mean	31,000	287	143	106

* As measured with an I.C.A.N. altimeter.

† The horizontal scale is the distance on the low-pressure side of the jet axis in which the wind speed falls to half its maximum value.

shown in Fig. 4. The positions of the various turbulent incidents relative to the jet stream are shown on this diagram. The mean cross-section was constructed as follows: cross-sections were drawn for each of the jet streams for approximately the same time as the turbulence was observed and for sections as near as possible to the position of the turbulence, using observations of wind and temperature from the British upper air observing stations. Reference lines were then drawn on each cross-section taking the jet centre (point of maximum wind) as origin. Horizontal distances were measured in units of the distance from the jet centre to the point, at the same level on the left of the jet looking downwind, at which the wind speed decreased to half its maximum value. Vertical distances were measured in pressure differences as indicated in Fig. 4 where a logarithmic scale is used so that ordinates on the diagram are approximately proportional to true height. Values of temperature, potential temperature and wind speed normal to the cross-section were then read off each diagram

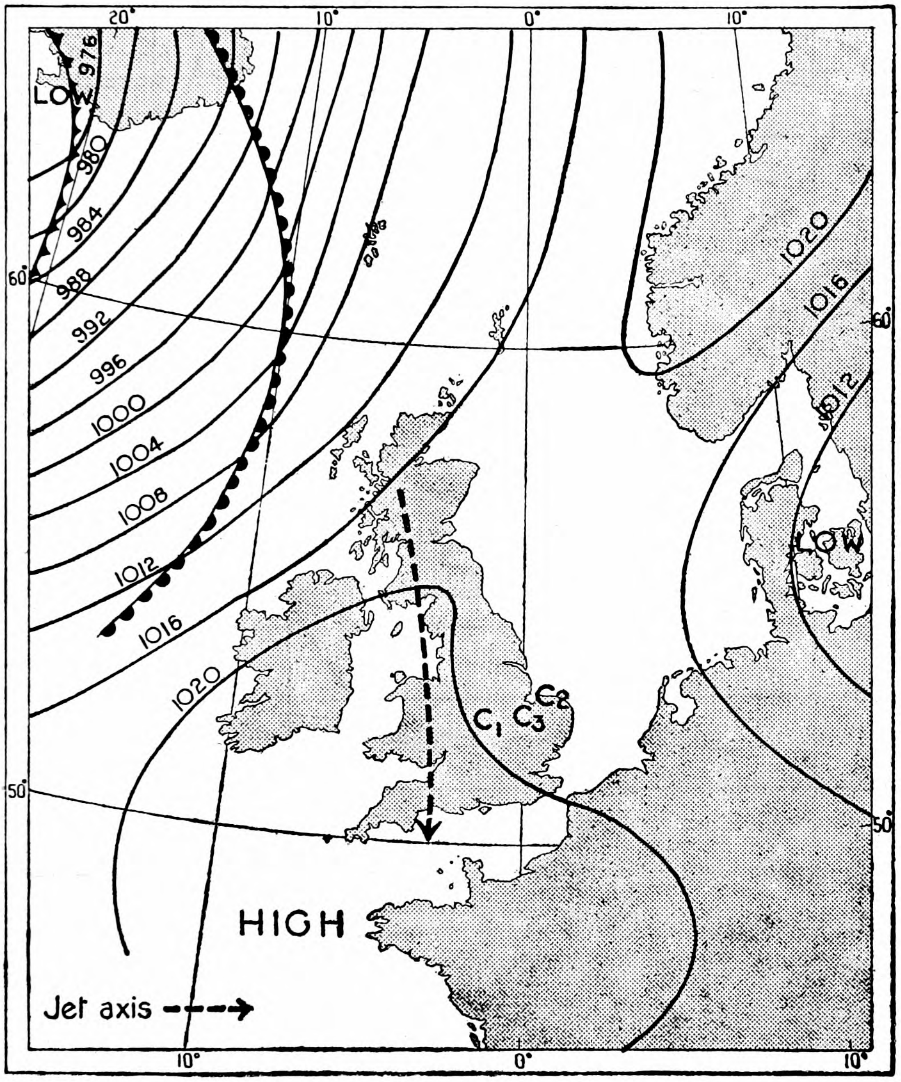

FIG. 3—SYNOPTIC CHART, 1200 G.M.T., NOVEMBER 7, 1950 SHOWING THE REGIONS OF OBSERVED TURBULENCE

for each point of the net of reference lines, wind speed being measured as a percentage of the maximum wind. The readings for corresponding points on the three cross-sections were then meaned and the resulting mean values led to the diagram in Fig., 4. The heights of the axes, the maximum wind speeds and the horizontal-distance scales for the three jet streams are given in Table II.

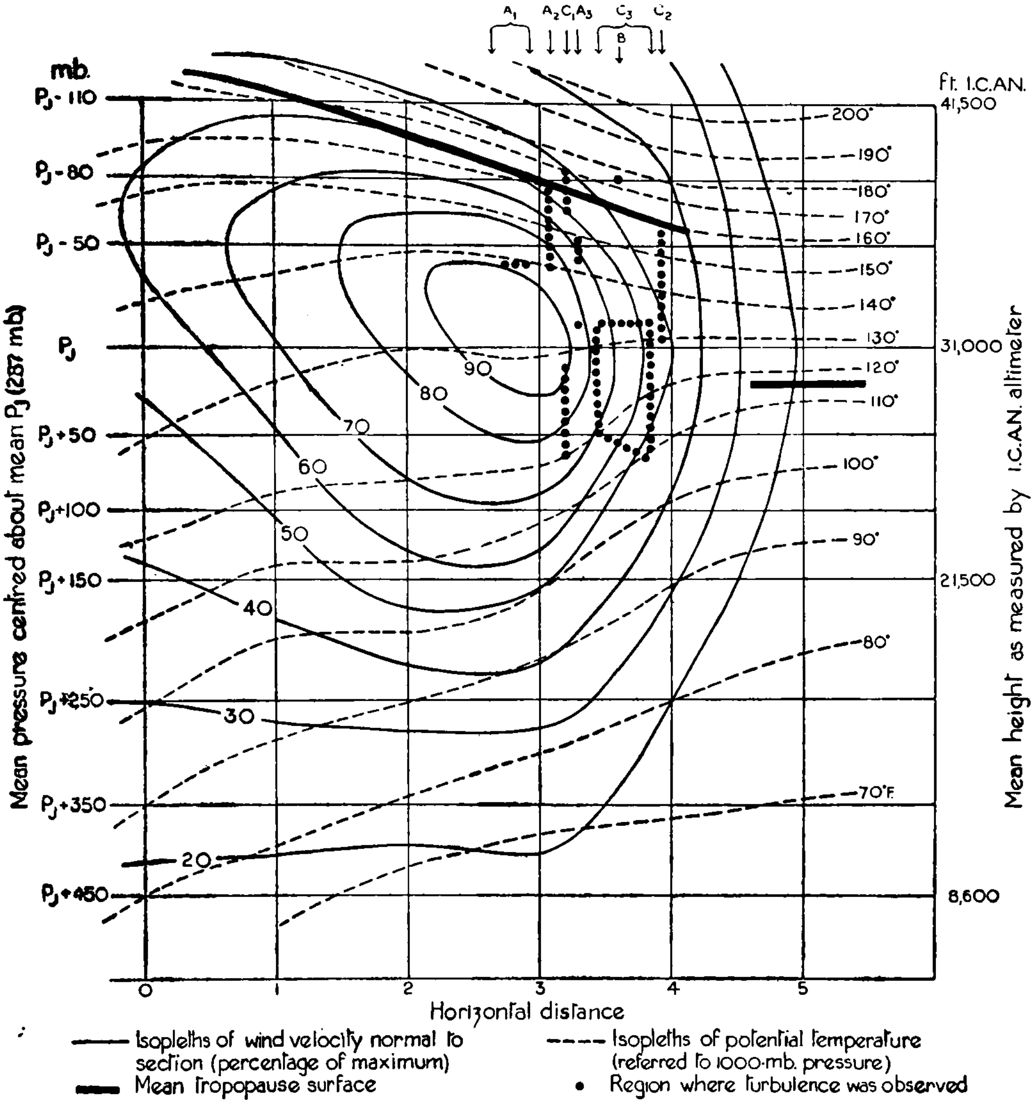

FIG. 4—MEAN CROSS-SECTION OF A JET STREAM SHOWING REGIONS OF TURBULENCE

The scales of units of horizontal distance are given in Table II.

In Fig. 4, isopleths of wind speed normal to the section, expressed as a percentage of the maximum, are given as full lines. The pecked lines show the isopleths of potential temperature which are also isentropes. The only forces opposing motion along isentropic surfaces are frictional so that turbulent transfer along the isentropic surfaces and across the wind (i.e. along the isopleths of potential temperature in the diagram) is easily effected.

A striking feature of Fig. 4 is that with the exception of incident A_1 the reported severe gustiness occurred on the low-pressure side of the jet axis. It must be remembered that only three occasions are considered here and that probably only small portions of the jet region were explored by aircraft on these days. It is not possible, therefore, to deduce with certainty that the low-pressure side of a jet stream is more liable to be turbulent than the anticyclonic side; there is at least one report of severe turbulence occurring on the anticyclonic side (November 30, 1950, over the Wash and Lincolnshire at 40,000 ft.). However, flights above 25,000 ft. are not uncommon so that severe turbulence on the high-pressure side of a jet stream should not go unnoticed for long if it occurs frequently. It is certainly suggestive that the noteworthy cases of severe gustiness in the neighbourhood of jet streams discussed in this note were all just above or on the low-pressure side of the axis. The two cases of severe turbulence encountered near jet streams by the British European Airways high-altitude experimental flights (Hislop[3]; flights VR 4 and VR 60) were also on the low-pressure side of the jet axis.

It is emphasized that this mean cross-section in Fig. 4 has been prepared merely as a convenient way of illustrating the positions of the gustiness observations relative to the jet stream. It is not claimed that this mean jet stream has any properties which can be interpreted physically except in so far as the properties are means of common features.

Probable causes of the gustiness.—In *Professional Notes* No. 104[1] it is shown that high-altitude gustiness is in most cases related to one or both of two meteorological parameters namely shear of wind in the vertical and shear of wind in the horizontal. The physical connexion between vertical wind shear and turbulence is easily visualized as similar to that resulting in turbulence in the shearing layer near the ground. The dimensionless quantity known as the Richardson number, which takes into account the vertical stability of the air as well as the wind shear, appears to be a useful parameter in this connexion. The Richardson number is defined as

$$R_i = \frac{g}{T}\frac{\left(\frac{\partial T}{\partial z} + \Gamma\right)}{\left(\frac{\partial \mathbf{V}}{\partial z}\right)^2}$$

where T is the absolute temperature, z is the height, Γ is the adiabatic lapse rate of temperature (dry- or wet-adiabatic as appropriate), and $\mathbf{V}$ is the wind velocity.

High-altitude turbulence is very often, but not always, associated with small values of R_i of the order 1–5*. In many cases, therefore, it seems reasonable to say that the gustiness encountered by aircraft is caused by abnormal vertical shear of wind.

It is more difficult to see a direct physical connexion between excessive wind shear in the horizontal and the occurrence of gustiness, and the mechanism whereby a horizontal shear of, say, 20 kt./100 nautical miles causes eddies of the order of 200 ft. across is not understood at present. The fact remains that there does appear to be some relation between the occurrence of turbulence at high altitude and abnormal wind shear in the horizontal.

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*RICHARDSON[7] deduced theoretically that when Ri is less than 1 turbulence should increase, and should decrease when Ri is greater than 1 but CALDER[8], among others, has shown that the critical value may be less than 1.

In Fig. 4 it is seen that in some cases, (e.g. A_2, A_3, C_1, parts of C_3) the gustiness occurred in regions of large shear in the vertical. Fig. 4 is, however, a composite diagram of three different occasions and the averaging process has probably masked individual peculiarities. Scrutiny of the upper wind data for each particular occasion shows that in every case the wind shear in the vertical was probably large and the Richardson number correspondingly small. On November 14, 1949, the Richardson numbers evaluated from each of the upper air observations made at 1430 G.M.T. at Larkhill, Downham Market and Leuchars were less than 1 at 35,000 ft. (incident A_1), and the Richardson numbers at Lerwick between 35,000 and 38,000 ft. and at Downham Market between 32,000 and 36,000 ft. (incidents A_2 and A_3 respectively) were also less than 1 at 1430. On November 2, 1950, the nearest wind observation to incident B was that made at Downham Market at 1430; there, again, the Richardson number was less than 1. The nearest upper air observations to incidents C_1, C_2 and C_3 on November 7, 1950, (Larkhill and Downham Market), indicated that the Richardson number was less than 1 in the turbulent layers with the exception of the upper layer of C_1 (39,000 to 41,000 ft.) where it had a value of 1·7.

Fig. 4 shows that in almost every case the horizontal shear (or the shear along the isentropic surfaces) was large in the gusty region being 0·2 $hr.^{-1}$ or more and the data for each of the individual cases confirm this.

Thus in these cases of severe gustiness it appears that both meteorological features which are favourable for the occurrence of turbulence were present. There is no way at present of determining which factor was the more important but ease of physical interpretation would point to strong wind shear in the vertical as the main cause of the gustiness.

Conclusions.—There seems little doubt that jet streams are favourable regions for the occurrence of turbulence of such a nature as to cause bumps to an aircraft. Since jet streams often extend as wandering high-speed currents over distances up to 1,000 miles or so they are frequently encountered on flights in the upper troposphere in temperate latitudes, and it is therefore important to discover as much as possible about the occurrence of turbulence in their neighbourhood. The three occasions analysed here, though providing only a limited amount of information, are thought to be useful examples and to form a basis of knowledge to which can be added further information as it becomes available. It is suggested that other interesting incidents of high-altitude gustiness can be added to a diagram such as Fig. 4, and eventually it may be possible to confirm the most turbulent regions of jet streams and whether there is any significant variation in the position of these regions relative to the jet axis, along the length of the jet stream.

Acknowledgment.—Details of the incidents on November 14, 1949, and November 2, 1950, were kindly supplied by the De Havilland Aircraft Company.

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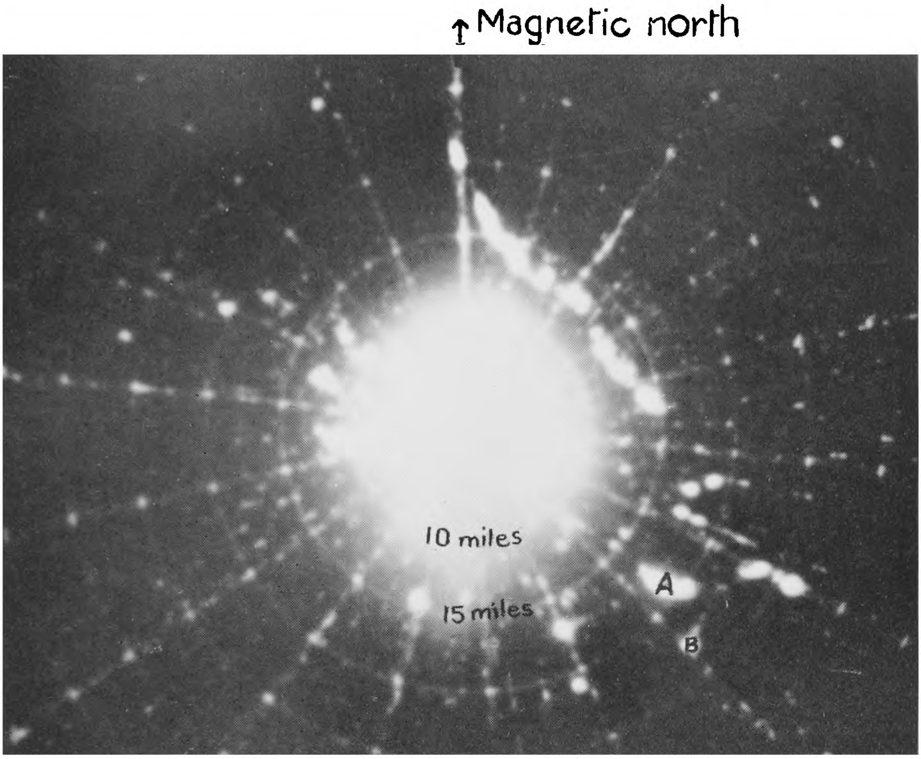

↑ Magnetic north
10 miles
15 miles
A
B

FIG. I—P.P.I. PHOTOGRAPH OF RAIN ECHOES FROM CLOUD NOT REACHING FREEZING LEVEL

Time of observation: 1501 G.M.T., July 18, 1951

(see p. 273)

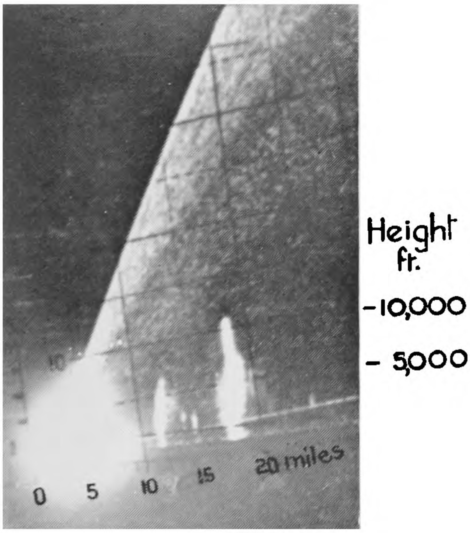

Height ft.
-10,000
- 5,000
10
0
5
10
15
20 miles

FIG. 2—VERTICAL CROSS-SECTION ON BEARING 134° MAGNETIC

Time of observation: 1459 G.M.T.

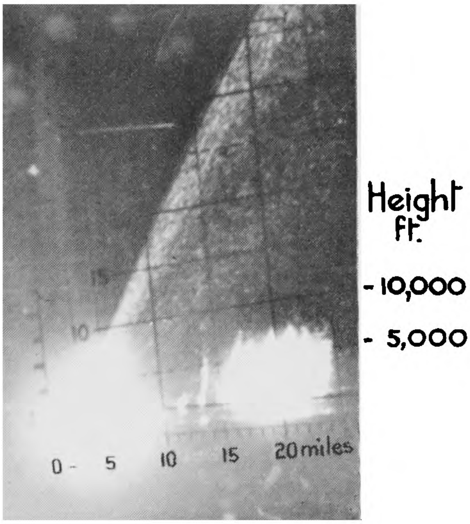
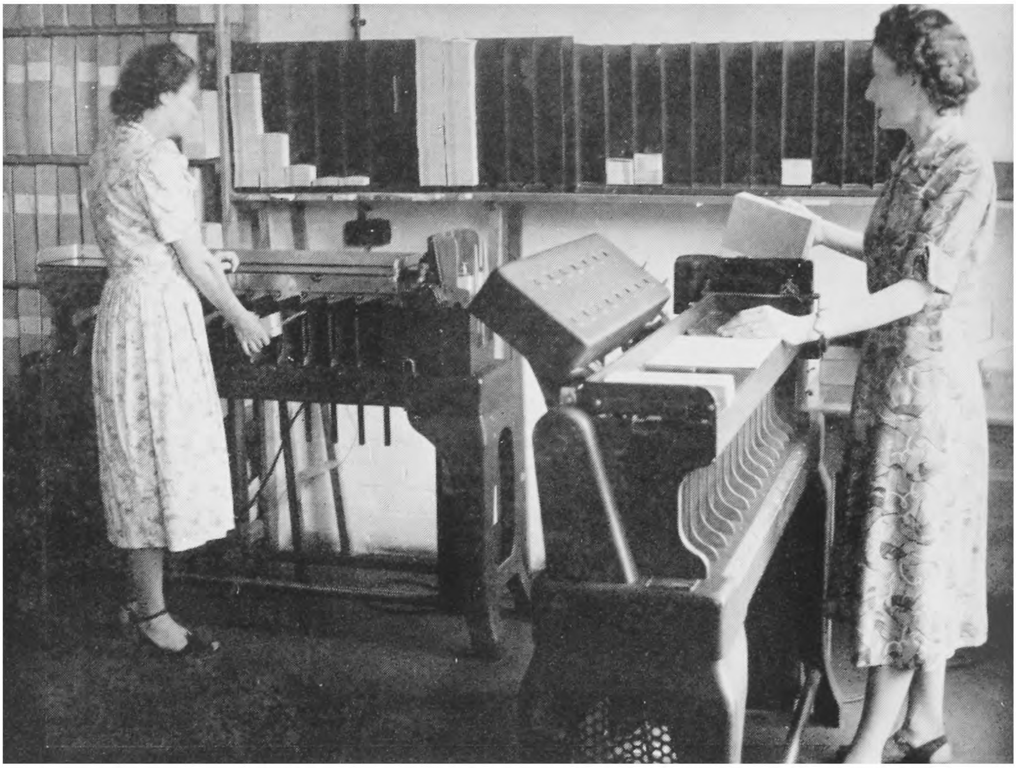
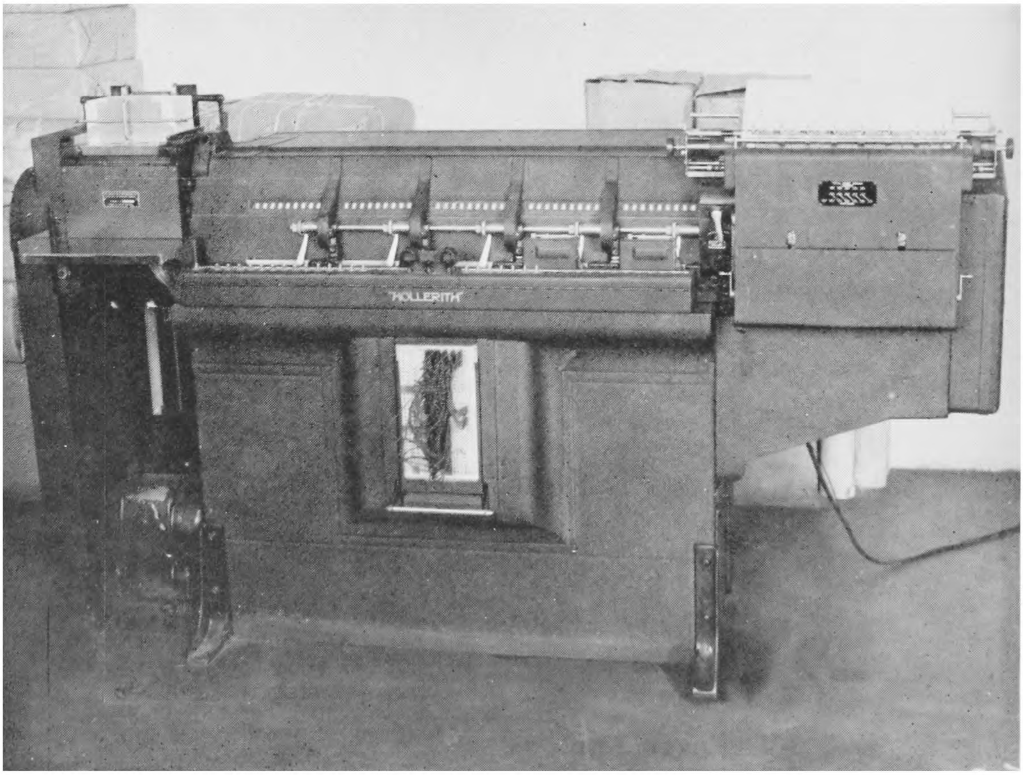

Height ft.
- 10,000
- 5,000
15
10
0 -
5
10
15
20 miles

FIG. 3—VERTICAL CROSS-SECTION ON BEARING 125° MAGNETIC

Time of observation: 1346 G.M.T.



PLAIN SORTER AND COUNTER-SORTER MACHINES



TABULATING MACHINE

MECHANICAL SORTING AND TABULATING MACHINES IN THE MARINE BRANCH OF THE METEOROLOGICAL OFFICE

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ADAPTATION OF MECHANICAL SORTING AND TABULATING MACHINES TO RESEARCH IN MARINE METEOROLOGY

By A. H. GORDON, M.S.

Mechanical sorting and tabulating machines are designed for the systematic analysis of large numbers of observations and they may be adapted to many kinds of scientific research problems. They are particularly suitable for the treatment of marine observations, and recent research in marine meteorology has been planned to make good use of the facilities that these machines are able to provide.

The general function and purpose of the machines have been described in a previous article.[1] It is the intention here to outline briefly ways in which the machines may be adapted to meet the requirements of specialized problems in marine meteorological research.

In the Marine Branch of the Meteorological Office there are two plain sorter machines, two counter-sorter machines and a tabulating machine. The plain sorter sorts the punched cards into the groups required, the counter-sorter counts the cards in each group as they are sorted and the tabulator tabulates the data, counts the total number of cards and the sum total of the tabulated values. The simplest analysis of data is the calculation of the mean of all the numerical values of a given meteorological element for a particular area, period or time of day or other boundary condition desired. It is also simple to compute the frequencies of occurrence of various meteorological phenomena or of ranges of values of specified elements, provided the ranges are not too small. The meteorological atlases of the oceans prepared by the Meteorological Office during the late war are based mainly on computations of this nature for two- or five-degree squares, grouped into months of the year.

An example of a more specialized problem is an investigation[2] into the influence of the strength of the wind on the sea and air temperature and the air-sea temperature difference. In this and other similar types of problems the observations are required to be sorted into groups and finally tabulated so that each of a range of values of a particular meteorological element is associated with the corresponding value of another meteorological element for the same observation. If, in the above mentioned problem, the sea and air temperatures were sorted in order from the maximum to the minimum values and these were tabulated for each wind force, a frequency curve of all the sea and air temperatures could be drawn for each wind force, and the mode and median of such a curve obtained. Such a curve could apply to a given area, time of day or time of year and also, if desired, to different wind directions. Each further limiting condition would require additional sortings.

In order to investigate the effect of the wind on the air-sea temperature difference it would be necessary to sort each final wind-force group so that each of the range of values of air temperature from the maximum to the minimum was associated with its corresponding sea temperature for the same observation. The tabulations would then appear in the general form given in the following example:—

Wind force	Air temperature	Sea temperature	Total number of each sea-temperature value for each air-temperature value
1	60	56	1
1		54	1
1	58	54	1
1		52	1
1	55	50	1
1	54	58	
1		58	
1		58	3
1		55	1
1	52	55	1
1		50	1
1	50	48	
1		48	
1		48	3
1		47	
1		47	2
1		46	1

and so forth for each wind-force group throughout the range of air-temperature values. From these tabulations a grid can be prepared which contains the frequency of each air-sea temperature difference (1°, 2°, 3°, etc.) for each air-temperature value. A percentage frequency curve of the whole range of air-sea differences could then be constructed for each wind force and the sets of curves so obtained compared with one another.

Similar types of problems that have been undertaken in marine meteorology are the diurnal variation of sea and air temperature in relation to cloud amount and to the air-sea temperature difference, and the influence of the strength of the wind on the relative humidity. In the latter problem the data would be tabulated as already shown except that wet-bulb observations would replace sea temperatures in the third column. The grid would then contain the frequency of each of the range of relative humidities associated with each value of the air temperature. In this case the curve constructed from the grid would give the percentage frequency of each of the range of relative humidities for each wind force. As before, the sets of curves could be compared with one another and their physical significance studied.

The above examples are only a few of the many problems to which mechanical sorting and tabulating machines may be adapted to convert raw marine data into a form readily used by the research worker. The potentialities of the machines in the furthering of research in marine meteorology are only limited by the ingenuity of the research worker himself.

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OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

PROFESSIONAL NOTES

No. 103—Stratus cloud near the east coast of Great Britain. By G. A. Bull, B.Sc.

Off-sea winds on the east coast of England are frequently accompanied by a sheet of low stratus cloud which is particularly persistent in winter and spring.

In this note the physics and variations of this cloud are examined; and a description is given of methods, tried in the Meteorological Office at Felixstowe, of forecasting the cloud.

No. 104—Meteorological aspects of turbulence affecting aircraft at high altitude. By J. K. Bannon, B.A.

This note describes the results of a meteorological analysis of occasions of turbulence (bumps) experienced by aircraft at high altitude. It is found that noticeable turbulence, which is not associated with cumulonimbus cloud, occurs not infrequently above a height of 20,000 ft. over the British Isles; it is rarely severe.

Statistics of the heights and depths of turbulent layers are given, and it is shown that turbulence occurs most frequently in the neighbourhood of the 30,000-ft. level and that the turbulent layers are usually less than 1,000 ft. thick. Bumps are often found near the tropopause. This turbulence is found to be related to the Richardson number (itself related to wind shear in the vertical and temperature lapse rate) and to the horizontal shear of the wind, but neither of these causes alone can explain all the occurrences of bumpiness and it seems that these two possible causes of turbulence are partly independent.

Well marked jet streams and their margins are regions of large shear in the vertical and in the horizontal, and high-altitude turbulence is frequently experienced in and near such fast-moving streams of air.

ROYAL METEOROLOGICAL SOCIETY

Visit to East Malling Research Station

This year, the annual summer meeting of the Royal Meteorological Society was held at East Malling, near Maidstone in Kent, on July 18.

The Society was welcomed by Dr. Tubbs, Director of the Station, and led at once to an improvised lecture theatre of apple boxes in a nearby orchard. Dr. Tubbs gave a brief talk on the general work of the station: research into the better understanding of fruit-growing and its relation to climate and soil; in this they were greatly helped by the Agricultural Meteorology Branch of the Meteorological Office. Climate had a long-term effect on the soil and this had a cumulative effect on the growth of a tree, and the effect of the weather in one particular year was carried forward to other years. In general, fruit-growing was successful in England south of the 68°F. mean isotherm in August, and the best-quality apples were grown with much sunshine and about 25 in. annual rainfall, very little of which should fall in spring. But growth was much influenced by day-to-day weather changes such as an isolated spring frost, waterlogging or increased attacks by harmful insects and diseases, all of which could affect growth in future years as well as in the present.

Orchards were nowadays planned to avoid frost hollows, but research into the favourable sites near the tops of hills was now necessary. And there was still the problem of the hardiness of individual buds, not the whole tree, and why, after a mild winter, some buds would not produce fruit. In studies of this nature the normal weather measurements were of little use and it was necessary to make accurate microclimatological measurements of the environment of an individual tree or branch or even bud.

Mr. Preston described some efforts that had been made to correlate time of blossoming with various meteorological and other factors, such as the monthly mean temperatures, the accumulation of day degrees above 42°F., the type of fruit and the age of the tree and method of pruning. With some trees the blossoming was a little later every year (after allowing for other factors), with others a little earlier. Eventually it had been possible to make in February a forecast with reasonable accuracy (±5 days normally, ±1 day in years of late and early blossoming) of the time of maximum blossoming, and therefore to know beforehand when to prepare for spraying and when to introduce bees. By pruning selectively the blossoming on different branches of the same tree could be arranged to come at different times within the normal blossoming period and so to be sure that some part of the blossom would always escape the effects of frost.

At another part of the station, Mr. Good demonstrated a tensiometer which had been designed by Dr. Rogers to measure the capillary tension of water in the soil. This consisted of a buried porous pot filled with water connected by tubing to a mercury manometer. It was shown being used under various surfaces—clean cultivation, grassing down and straw mulch. When the water content was low the tension was high and the mercury in the tensiometer was low and *vice versa*, the limit of measurement being, of course, 1 atmosphere of pressure. The experiments showed that the straw mulch acted as a blanket to radiation and enabled the water from quite a slight shower to be collected. Also, transpiration from grass in dry weather seemed to be offset by improved penetration of rainfall. While the Society was at the Station the tensiometers were reading about 7 cm. of mercury over the straw mulch and cultivated plots but 60 cm. over the grass plots.

Mr. Ruxton described some experiments on the effect of frost. The temperature of the plants was measured by a fine-wire thermocouple (the wires were so fine they were almost invisible from 15 ft.) which was accurate to approximately 0·1°C. On some occasions of radiational cooling below 0°C. the plant did not freeze, i.e. there was supercooling. The explanation for this supercooling was unknown. A method, still experimental, of preventing the freezing of flowers (or blossoms) during a frosty night was demonstrated in a cold chamber. The flower was sprinkled with a fine shower of water which froze on contact with the flower. This liberated latent heat which was sufficient to maintain the temperature of the flower at only 0·1°C. below freezing. The temperature of a flower in the same chamber but not sprinkled fell to −3°C. and the flower was killed. The method had not, so far, been tested on an orchard scale because of the lack of frost during this spring!

After tea (at which there were home-grown cherries) the Society inspected one of the classical root-stock experimental plots where the root-stocks had been standardized to such an extent that it was now possible to control the size, shape and fruit-bearing qualities of a given root-stock and sire.

Another plot was given over to entomological experiments and Miss Groves gave a short lecture on the character of red-spider-mite migration. If there was any wind at all the tiny red-spider mites clung to the leaves of the trees; in a calm they spun a thread from which they dangled to be blown away by the next breeze.

In the model garden, which the Society visited last, cordon apple trees were on exhibition in all manner of shapes, one of the best (possibly because of its efficiency as a receiver of insolation) being in straight lines at 45° to the horizontal with no real branches at all. A plum tree, growing against a wall, was shown also supplied with a hessian cover for use on radiation nights. This raised the temperature of the plant 5°F. above the air temperature whereas the traditional fish-netting had almost no effect.

Mr. E. L. Hawke, on behalf of the Society, offered sincere gratitude to the staff of the Research Station for the excellent organization and the great amount of work that had been done to make the visit a success.

LETTER TO THE EDITOR

Rain from non-freezing clouds

As rain from non-freezing clouds has not been reported before in England, the following observations may be of interest.

From 1300 to 1630 G.M.T. on July 18, 1951, numerous echoes from precipitation were observed on 10-cm. radar at East Hill on bearings principally between east and south. The maximum top of echo observed was 8,500 ft., and some echoes with tops only 1,000–2,000 ft. were seen to persist for a considerable time. The echoes frequently showed a column structure and were visible, with quite high intensity, at ranges up to 30 miles.

We were able to make contact with a Hastings aircraft of the Meteorological Research Flight and direct it to two of the column-type echoes. The clouds containing the echoes could be distinguished from the aircraft by the domed tops rising about 500 ft. above the general 8 oktas stratocumulus cloud tops. The only cloud above this level was a trace of cirrus. Readings made in the aircraft showed the cloud tops examined to be at 7,500 and 8,800 ft. (I.C.A.N.) and the temperatures of the free air at these heights 45·7° and 44·6°F. respectively. Because these clouds were in the London Control Zone it was not possible to enter them but some distance away the clouds were found to contain a surprising amount of free water with some large drops.

Reports received make it clear that slight rain, in moderately sized drops, did reach the ground in the general area from which echoes were received and there is no doubt that the rain observed fell from non-freezing clouds.

Radar photographs are reproduced facing p. 268.

Fig. 1, a P.P.I. photograph, shows echoes from precipitation visible in a belt from 20 miles range on magnetic north to 15 miles on 090°. There are patches of precipitation echo to the south-east, the one marked A being from the second cloud examined by the aircraft which is at B.

Fig. 2 shows a vertical cross-section on a magnetic bearing of 134°. The echo at 17–19 miles is from the second cloud examined and is echo A of Fig. 1. The top of this echo is at about 8,000 ft. and merges into the echo from the aircraft which was at 8,800 ft. as it flew past the top of the cloud. Fig. 3, a vertical cross-section on a magnetic bearing of 125°, shows a quite extensive echo from 13–25 miles with top not exceeding 8,000 ft.

R. F. JONES

East Hill, near Dunstable, Bedfordshire, July 19, 1951

NOTES AND NEWS

Weather Control Bill

The February 1951 number of *Weatherwise*, organ of the amateur Weathermen of America, received in the Meteorological Office in June contains an article by Senator Clinton P. Anderson (New Mexico) on the Weather Control Bill he has introduced into the United States Congress. A brief summary of this article is published by permission of the Editor of *Weatherwise*.

The Bill is in general based on the United States Atomic Energy Act of 1946. If passed it will place weather modification and control activities in the United States under the exclusive control of the Federal Government. The Senator considers that, though the extent to which measures for weather control may be utilized is still speculative, the possible effects on the national life, economy, and military defence are so large as to call for control by the central government.

The Bill provides for the organization of a Weather Control Commission which would licence and assist institutions engaged in weather control, for work by the armed forces of the United States on the military aspects, and finally for participation by the United States in international measures. The Commission would be specifically authorized to exempt from its licensing requirements such minor aspects of weather control as the protection of fruit trees from frost by " smudging ".

WEATHER OF JULY 1951

Mean pressure was between 1020 and 1025 mb. over the Atlantic between 35°N. and 50°N. Mean pressure over Europe and the Mediterranean was generally between 1015 and 1020 mb., but over Scandinavia, Iceland and Greenland, it was below 1010 mb. Pressure was about 2 mb. above normal over the Atlantic and west Europe and about 2 mb. below normal over Scandinavia. Pressure over North America was generally normal.

Mean temperature over most of the British Isles and Europe including southern Scandinavia was between 60° and 70°F. and reached 75°F. in Spain and the Mediterranean. In west Africa mean temperature was between 75° and 95°F. and exceeded 100°F. at places in the region of the Sahara. Mean temperature was generally about 2°F. above normal over Europe, but 3° to 4°F. below normal over Scandinavia.

In the British Isles the month was rather warm with several fine spells of abundant sunshine, especially in the south. These were interspersed with briefer cool periods and outbreaks of thundery rain. In general, rainfall was on the low side, but irregular in its distribution both in time and space.

From the 1st to the 3rd pressure was high to the south-west with fine warm weather over England and Wales; maximum temperatures in the neighbourhood of 80°F. and bright sunshine exceeding 13 hr. in the day were not uncommon. There were, however, troughs of low pressure over Scotland and one of these moved south with a break-through of polar air which covered the whole country on the 4th and 5th. Weather became cooler and cloudier everywhere, the effect being strikingly shown at Felixstowe with a maximum temperature of 81°F. on the 3rd but only 65°F. on the 4th. A westerly type of weather became established on the 6th bringing cool showery conditions to all districts until the 8th, though rainfall was slight in the south. On the 9th a fairly deep depression approached Ireland and then, gradually filling up, moved slowly across Scotland on the 10th and 11th to reach southern Norway on the 14th. Rain fell in all districts, though it was heaviest in the north where there were widespread thunderstorms on the 10th and 11th. A small secondary disturbance moving north-east along the English Channel brought heavy rain to the south-east and east on the 12th and thundery outbreaks to central districts; 2·04 in. of rain fell at Great Bealings in Suffolk and 2·31 in. at Longfield in Kent. High pressure developed behind the depression on the 13th and became established as an anticyclone centred to the south-west which persisted until the 21st. Though there was somewhat unsettled weather in the north, the south experienced a warm dry period with maximum temperatures again approaching 80°F. and exceeding this value at some places during the last few days. On the 20th the centre of high pressure began to shift towards the east, crossing England on the 21st and reaching central Europe on the 22nd. It was followed by a complex depression which, forming off the south-west coast, moved north-east to reach the North Sea early on the 23rd. Widespread thunderstorms occurred on the 22nd, with special severity in southern England where some deaths from lightning and considerable damage were reported; 2·11 in. of rain fell at Romsey in Hampshire. Polar air in the rear of this depression affected north-west Scotland on the 22nd and covered the whole country on the 23rd, with dull cool weather in most districts; the maximum temperature was 56°F. at Cranfield, Lincolnshire, and exceeded 65°F. at a few places only. High pressure to the south-west again dominated the situation on the 24th and 25th. It was, however, rather unsettled in the north, and these conditions spread south, with some rain in Wales and the Midlands, on the 26th and 27th. Weather in the south was relatively unaffected and became very warm again on the 28th. A further short spell of generally fine weather on the 29th and 30th was associated with the eastward movement of an anticyclone across the country, but a depression moving north from Biscay brought widespread thunderstorms over southern and midland districts on the night of the 30th–31st. There was heavy rainfall followed by lighter falls on the 31st in the north as cloudier conditions spread to all districts.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	86	36	+0·9	67	−3	108
Scotland	79	31	+0·3	116	+1	91
Northern Ireland ...	74	39	+0·1	109	−2	79

RAINFALL OF JULY 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·46	61	*Glam.*	Cardiff, Penylan ...	·99	32
Kent	Folkestone, Cherry Gdn.	1·32	63	*Pemb.*	Tenby	1·06	36
,,	Edenbridge, Falconhurst	2·56	110	*Card.*	Aberystwyth	4·31	142
Sussex	Compton, Compton Ho.	2·33	82	*Radnor*	Tyrmynydd	2·08	51
,,	Worthing, Beach Ho. Pk.	2·77	136	*Mont.*	Lake Vyrnwy	2·71	76
Hants.	Ventnor, Cemetery ...	1·58	77	*Mer.*	Blaenau Festiniog ...	5·24	61
,,	Bournemouth	1·19	56	*Carn.*	Llandudno	·85	38
,,	Sherborne St. John ...	1·36	61	*Angl.*	Llanerchymedd ...	1·47	72
Herts.	Royston, Therfield Rec.	1·33	53	*I. Man*	Douglas, Borough Cem.	2·06	67
Bucks.	Slough, Upton... ...	1·33	69	*Wigtown*	Port William, Monreith	2·34	83
Oxford	Oxford, Radcliffe ...	1·34	57	*Dumf.*	Dumfries, Crichton R.I.	2·54	78
N'hants.	Wellingboro', Swanspool	·82	36	,,	Eskdalemuir Obsy. ...	4·68	114
Essex	Shoeburyness	2·41	132	*Roxb.*	Kelso, Floors	3·26	124
,,	Dovercourt	2·02	101	*Peebles*	Stobo Castle	3·18	110
Suffolk	Lowestoft Sec. School ...	3·08	136	*Berwick*	Marchmont House ...	2·57	84
,,	Bury St. Ed., Westley H.	1·40	56	*E. Loth.*	North Berwick Res. ...	3·28	127
Norfolk	Sandringham Ho. Gdns.	1·48	58	*Midl'n.*	Edinburgh, Blackf'd. H.	3·50	124
Wilts.	Aldbourne	1·37	58	*Lanark*	Hamilton W. W., T'nhill	2·46	86
Dorset	Creech Grange... ...	1·19	49	*Ayr*	Colmonell, Knockdolian	1·98	63
,,	Beaminster, East St. ...	2·79	107	,,	Glen Afton, Ayr San ...	2·88	69
Devon	Teignmouth, Den Gdns.	1·82	78	*Bute*	Rothesay, Ardencraig...	3·69	93
,,	Cullompton	1·26	47	*Argyll*	Morvern, Drimnin ...	6·22	141
,,	Ilfracombe	1·20	47	,,	Poltalloch	5·23	127
,,	Okehampton, Uplands	3·54	109	,,	Inveraray Castle ...	5·74	115
Cornwall	Bude, School House ...	1·03	42	,,	Islay, Eallabus... ...	2·83	83
,,	Penzance, Morrab Gdns.	1·07	39	,,	Tiree	3·28	91
,,	St. Austell	1·72	51	*Kinross*	Loch Leven Sluice ...	5·83	202
,,	Scilly, Tresco Abbey ...	·48	22	*Fife*	Leuchars Airfield ...	4·32	166
Glos.	Cirencester	1·94	75	*Perth*	Loch Dhu	4·22	87
Salop	Church Stretton ...	2·36	89	,,	Crieff, Strathearn Hyd.	2·92	98
,,	Shrewsbury, Monksmore	1·63	78	,,	Pitlochry, Fincastle ...	2·30	86
Worcs.	Malvern, Free Library	·98	43	*Angus*	Montrose, Sunnyside ...	3·32	126
Warwick	Birmingham, Edgbaston	1·06	46	*Aberd.*	Braemar	2·24	87
Leics.	Thornton Reservoir ...	1·07	43	,,	Dyce, Craibstone ...	5·75	190
Lincs.	Boston, Skirbeck ...	1·08	49	,,	Fyvie Castle	4·66	143
,,	Skegness, Marine Gdns.	·71	33	*Moray*	Gordon Castle	3·45	108
Notts.	Mansfield, Carr Bank...	·72	27	*Nairn*	Nairn, Achareidh ...	2·94	115
Derby	Buxton, Terrace Slopes	2·83	72	*Inverness*	Loch Ness, Garthbeg ...	3·38	107
Ches.	Bidston Observatory ...	1·16	45	,,	Glenquoich	7·66	119
Lancs.	Manchester, Whit. Park	3·25	98	,,	Fort William, Teviot ...	5·52	113
,,	Stonyhurst College ...	3·93	102	,,	Skye, Duntuilm ...	6·13	163
,,	Squires Gate	1·60	57	*R. & C.*	Tain, Tarlogie House ...	2·74	100
Yorks.	Wakefield, Clarence Pk.	2·96	117	,,	Inverbroom, Glackour...	3·06	82
,,	Hull, Pearson Park ...	1·54	66	,,	Applecross Gardens ...	5·43	136
,,	Felixkirk, Mt. St. John	3·06	112	,,	Achnashellach	7·31	150
,,	York Museum	2·23	88	,,	Stornoway Airfield ...	3·40	118
,,	Scarborough	2·52	104	*Suth.*	Loch More, Achfary ...	7·09	133
,,	Middlesbrough... ...	1·89	74	*Caith.*	Wick Airfield	3·71	141
,,	Baldersdale, Hury Res.	1·05	33	*Shetland*	Lerwick Observatory ...	3·97	173
Norl'd.	•Newcastle, Leazes Pk....	1·55	61	*Ferm.*	Crom Castle	3·63	104
,,	Bellingham, High Green	1·71	52	*Armagh*	Armagh Observatory ...	3·34	116
,,	Lilburn Tower Gdns. ...	2·62	106	*Down*	Seaforde	3·21	101
Cumb.	Geltsdale	4·15	120	*Antrim*	Aldergrove Airfield ...	3·31	118
,,	Keswick, High Hill ...	3·07	80	,,	Ballymena, Harryville...	3·55	104
,,	Ravenglass, The Grove	3·14	84	*L'derry*	Garvagh, Moneydig ...	3·79	117
Mon.	Abergavenny, Larchfield	·95	38	,,	Londonderry, Creggan	3·49	95
Glam.	Ystalyfera, Wern House	1·37	30	*Tyrone*	Omagh, Edenfel ...	2·94	116

M.O. 548 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

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THE DISTRIBUTION OF MEDIUM AND HIGH CLOUD NEAR THE JET STREAMS

By J. S. SAWYER, M.A. and B. ILETT

Introduction.—Narrow belts of strong winds are a recognized feature of synoptic charts for levels in the upper troposphere* and have come to be known as "jet streams". The best defined maxima of wind appear to occur in relatively straight stretches of the meandering belt of the upper westerly current of the hemisphere. These narrow bands of strong upper winds persist from one chart to the next and must form stable dynamical systems. It might therefore be expected that features of the flow in the upper troposphere and associated cloud systems would show a closer relation to the position and movement of the axis of the jet stream than to the synoptic systems of the surface pressure field.

An investigation was undertaken recently at the Central Forecasting Office, Dunstable, in order to ascertain whether the distribution of medium and high cloud near the jet stream followed a recognizable pattern. If such a pattern existed it would be of value in the analysis of high-level charts when few upper air soundings were available; it might also permit the navigator of an aircraft to recognize his position with respect to the jet stream from the state of the sky.

The available data consisted of the synoptic reports received at the Central Forecasting Office (both surface observations and upper air soundings) together with the analysed charts. On the basis of these observations some uncertainty exists regarding the position of the axis of the jet stream; even over the British Isles it would not be expected that one could place the axis with a much smaller error than 200 miles the average distance between upper soundings; in other areas the errors would be greater. A less obvious uncertainty arises from reports of medium and high cloud. The estimation of the amount of high cloud is not easy, more especially when low cloud is also present; nor is the classification of the medium and high clouds according to the international codes entirely unambiguous. No doubt cirrus and medium cloud structures vary considerably from place to place, but reported amounts and types differ between stations so close together that the observers must be viewing the same clouds over at least part of the sky.

For these reasons it seemed unlikely that a direct examination of synoptic charts would give a true picture of the distribution of upper cloud around the

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*DURST, C. S. and DAVIS, N. E.; Jet streams and their importance to air navigation. *J. Inst. Navig., London*, **2**, 1949, p. 210.

jet stream on individual occasions. A complete and accurate picture of the cloud distribution round any particular jet stream could only be obtained by a specially organized network of ground and air observations. It was therefore necessary to adopt a statistical approach in the hope that any relationships between cloud and jet stream, which are sufficiently regular to be of interest, would be brought out statistically despite errors and deficiencies in individual cases.

Method of analysis.—The period covered by the analysis was the year 1949. Occasions of jet streams passing over or within about 500 miles of the British Isles were noted by examination of the 300-mb. contour charts drawn regularly at the Central Forecasting Office. For this purpose a belt of approximately straight flow with a maximum wind speed (observed or geostrophic) at 300 mb. of 70 kt. or more was taken as defining a " jet stream ". However, in order to see if the chosen lower limit of velocity had any effect on the results, the statistical analysis was also completed separately for those cases in which the wind speed exceeded 120 kt. The axis of the jet stream, that is the line of greatest velocity, was noted on the charts for 1500 G.M.T. each day, and the distribution of medium and high cloud examined in relation to this.

All available observations of medium and high cloud for 1500 G.M.T. were analysed in relation to their position with respect to the axis of the jet stream. The present scheme of synoptic reporting does not make provision for reports of the amount of the medium and high cloud layers on all occasions. However, an estimate of the amount of both medium and high cloud was made on the basis of the total amount of cloud reported and the amounts reported in lower cloud layers. For this purpose it was assumed that the same proportion of the whole sky was covered by medium and high cloud as in the part of the sky visible through the low cloud. If the amount of low cloud was less than 4 oktas and no upper cloud was reported both cirrus and medium cloud were assumed to be absent. Occasions of 4 oktas of low cloud or more and no medium cloud or cirrus observed were not included in the statistical summaries.

Statistical results.—In order to analyse the distribution of cloud in relation to the axis of the jet stream, the area round the jet stream was divided into eight sectors as indicated in Fig. 1. The area was divided first into bands parallel to the jet stream and 200 miles wide, and secondly by a line perpendicular to the axis through its mid point, dividing the jet stream into two equal sections longitudinally from the entrance to the mid point and from the mid point to the exit. The letters in Fig. 1 have been used to define the sectors in the tabular results.

The results of the statistical analysis is given in Tables I and II. The number of occasions of particular amounts and types of medium and high cloud is expressed as a percentage of the number of occasions for which observations of medium and high cloud respectively or their absences were available in the particular sectors. It must be remembered in considering these figures that observation of medium and high cloud was prevented by low cloud on a considerable number of occasions, and that, with broken low cloud (4 oktas or more), observations of medium and high cloud have been included but observations of their absence under these circumstances have been omitted. However the purpose of the present investigation was to establish if any pronounced relationship between the jet stream and upper cloud existed, and statistical

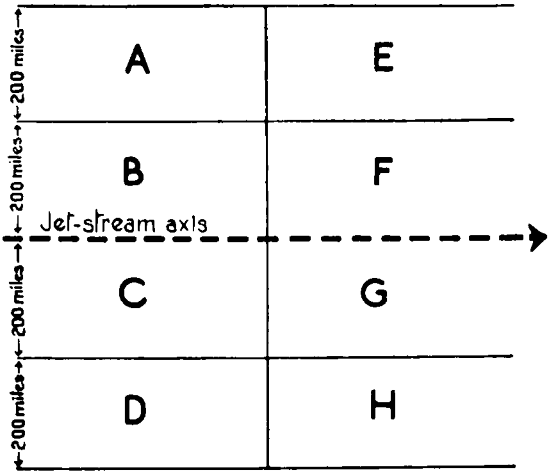

FIG. 1—SECTORS USED FOR STUDY OF CLOUD DISTRIBUTION IN RELATION TO THE JET STREAM

corrections for the unrepresentative nature of some of the data have not yet been attempted.

The most noteworthy features of Tables I and II are the following:—

(*a*) Amounts of cirrus of 4 oktas or more are considerably more frequent to the right of the axis of the jet stream (sectors C, D, G and H) than to the left (sectors A, B, E and F). This is brought out in Table III which gives the percentage frequency of cloud 4 oktas or more to the left and right of the jet-stream axis. The relationship was slightly more pronounced with the stronger jets.

There is little difference between the sectors longitudinally along the jet in respect of high-cloud amount, but this is not to be interpreted

TABLE I—FREQUENCY OF MEDIUM AND HIGH CLOUD AMOUNTS IN VARIOUS SECTORS OF THE JET STREAM

Percentage of the total number of observations of medium or high cloud together with observations of no medium or high cloud and low cloud less than 4 oktas. Maximum speed in jet stream >70 kt.

Sector	Cloud amount (oktas)					Total No. of obs.	Sector	Cloud amount (oktas)					Total No. of obs.
	0	1-3	4	5-7	8			0	1-3	4	5-7	8	
	percentage frequency							*percentage frequency*					
MEDIUM CLOUD													
A	38	23	17	16	6	154	E	34	16	15	20	16	335
B	50	21	12	11	5	256	F	34	21	12	18	15	574
C	30	25	15	21	10	334	G	36	16	12	20	16	764
D	31	17	14	24	14	177	H	34	12	13	23	17	641
HIGH CLOUD													
A	37	44	12	6	1	95	E	37	46	10	5	2	205
B	45	30	16	7	2	201	F	58	27	5	8	1	308
C	22	49	19	8	2	192	G	31	35	18	12	4	458
D	29	32	23	11	5	104	H	29	36	17	17	1	369

TABLE II—FREQUENCY OF MEDIUM AND HIGH CLOUD TYPES IN VARIOUS SECTORS OF THE JET STREAM

Percentage of the total number of observations of medium or high cloud together with observations of no medium or high cloud and low cloud less than 4 oktas. Maximum speed in jet stream >70 kt.

Sector	Cloud type*										Total No. of obs.	Sector	Cloud type*										Total No. of obs.
	0	1	2	3	4	5	6	7	8	9			0	1	2	3	4	5	6	7	8	9	
	percentage frequency												*percentage frequency*										
MEDIUM CLOUD																							
A	38	2	6	7	9	2	26	9	1	1	154	E	34	5	14	7	7	1	19	13	1	0	335
B	50	2	5	10	7	2	14	9	0	<1	256	F	34	4	12	9	7	1	20	12	1	<1	574
C	30	4	6	13	11	2	8	22	3	1	334	G	36	5	12	9	10	2	10	15	1	<1	764
D	31	5	12	9	9	2	0	21	7	3	177	H	34	6	12	11	11	2	4	19	1	1	641
HIGH CLOUD																							
A	37	9	15	23	5	2	2	2	0	4	95	E	37	11	15	22	1	3	4	2	3	2	205
B	45	9	9	15	3	3	9	1	4	2	201	F	58	5	5	15	2	4	5	2	3	1	308
C	22	21	17	8	2	5	10	4	6	5	192	G	31	15	18	6	2	7	6	4	4	5	458
D	29	15	22	2	5	8	6	7	4	3	104	H	29	19	19	3	3	6	8	2	5	5	369

*International code figures as used in 1949 (see " Handbook of weather messages, codes and specifications ", London, 1949, Part II, pp. 20 and 21).

as indicating no difference between the entrance and exit to the jet stream —probably only a few of the observations are really close to either the exit or entrance; the observations are mainly typical of the central region.

The more or less corresponding increase of cirrus amounts from sector A to D and from E to H lends support to the reality of the distribution of high cloud. Cirrus was not reported from sector D in the jet streams exceeding 120 kt.

(*b*) Medium-cloud amounts appear to be less in sectors A and B, i.e. the left entrance to the jet, but the amounts in other sectors show little variation.

(*c*) The statistics of cirrus types show, as would be expected, a dominance of cirrus type 3 (anvil cirrus) to the left of the jet stream and a relative abundance of the frontal and layer types of cirrus to the right. Again the relationship was slightly better developed with the stronger jets. In order to bring out the difference between the character of the cirrus cloud Table IV gives the frequencies of the layer types of cirrus (types 4–8), and the frequency of no cirrus and anvil cirrus (type 3) added together for the various sectors.

(*d*) The statistics of medium-cloud types show a remarkable predominance of type 6 (altocumulus formed by the spreading out of cumulus) to the left of the jet stream. Altostratus, frontal type of altocumulus and altocumulus castellatus are more common to the right of the jet.

TABLE III—PERCENTAGE FREQUENCY OF MEDIUM AND HIGH CLOUD 4 OKTAS OR MORE TO THE LEFT AND RIGHT OF THE JET STREAM

To the left of jet stream (sectors A, B, E and F)		To the right of jet stream (sectors C, D, G and H)	
All jet streams >70 kt.	Strong jet streams >120 kt.	All jet streams >70 kt.	Strong jet streams >120 kt.
	percentage frequency		
MEDIUM CLOUD			
41	37	50	60
HIGH CLOUD			
19	18	34	39

TABLE IV—PERCENTAGE FREQUENCY OF LAYER TYPE CIRRUS AND NO CIRRUS OR ANVIL CIRRUS IN VARIOUS SECTORS

Sector	All jet streams >70 kt.	Strong jet streams >120 kt.	Sector	All jet streams >70 kt.	Strong jet streams >120 kt.
	percentage frequency			*percentage frequency*	
LAYER TYPE CIRRUS					
A	12	15	E	14	14
B	20	18	F	16	15
C	27	35	G	24	24
D	29	44	H	24	36
NO CIRRUS OR ANVIL CIRRUS					
A	60	62	E	59	70
B	51	67	F	72	79
C	30	32	G	37	37
D	31	0	H	32	19

Notes on individual jet streams.—For several jet streams fairly complete sets of observations of cirrus cloud were available. It was noteworthy that on most occasions when a clear limit to an area of cirrus could be defined, this limit lay close to the axis of the jet stream. These were mainly the cases in which the jet stream was associated with an active front. On the other hand there were a number of jet streams through surface ridges of high pressure in which upper cloud amounts were small or zero in all sectors for which observations were available.

Conclusions.—There is statistical evidence that cirrus cloud is considerably more frequent and extensive to the right of the axis of the jet stream than to the left. The frontal and layer types of cirrus and medium clouds are more common to the right of the jet stream; anvil cirrus and altocumulus from the spreading out of cumulus are more common to the left. There is some suggestion from the study of individual cases that when a well defined boundary to the frontal cirrus occurs the axis of the jet stream is found close to this boundary, but the evidence is insufficient to establish this with certainty. There is little evidence for any variation of the cloud distribution along the length of the jet stream except for the relatively low frequency of medium cloud in the left entrance. However, the mode of analysis was not suitable to bring out features which affect only small areas near the exit or entrance of the jet stream.

AN AUTOMATIC SELECTING DEVICE FOR "SFERIC" OBSERVATIONS

By A. L. MAIDENS, B.Sc.

A full account of the "sferic" system for the location of thunderstorms, and of the operational methods employed, was given by C. V. Ockenden in the *Meteorological Magazine* for April 1947. In brief the system depends on the measurement at four remotely separated stations of the directional bearing of the atmospheric produced by a single lightning flash.

It will be appreciated that as practically all lightning flashes within a radius of at least 1,500 miles from the British Isles produce measurable signals on the apparatus, some degree of selection must usually be exercised. When the activity is considerable it is impracticable to locate all lightning flashes occurring within this area. It suffices to obtain sufficient observations to identify each active storm centre.

For this purpose a random selection of flashes is required to be observed, no preference being given either to direction or to signal strength, providing, of course, this is sufficient to give a readable signal.

In practice it has been found that visual selection by an observer at the control station may not necessarily be truly random, and that there can be a tendency both to over-select in particular directions, and to ignore weaker signals in preference to the stronger ones. Thus the more active or nearer storms may be represented by an excessive number of fixes, while weaker or more distant activity remains unrecorded, or supported only by a minimum of evidence.

To overcome this limitation in the " sferic " system it was recently decided to proceed with the design of an automatic selecting device, the requirement for which was that it would be actuated by any reasonable strength of signal. It was furthermore necessary for the apparatus to emit an audible warning note simultaneously with the arrival of the incoming signal, and for there to be a time delay between the lightning flashes so selected.

Mr. N. Lewis of the cathode-ray direction-finding unit at Dunstable has now designed and constructed equipment which meets all these requirements and which has given entire satisfaction in operation. It was found by trial that a minimum time-delay of about seven seconds allowed each set of bearings to be read, transmitted and recorded at Dunstable without undue haste.

In order that the warning signal could be transmitted over the private telephone lines of the " sferic " network, an audible note of a pitch in the range 800–1,000 c./sec. was chosen. The sharp "pip" emitted by the warning apparatus was found to stimulate the response of the observers, and obviated the possibility of reading an incorrect signal, when flashes occurred in quick succession.

The visual indication of lightning flashes given by the cathode-ray tube of the sferic equipment remains unaffected by this additional apparatus, and such flashes remain observable even during the time-delay period of the selecting device. Thus it is possible, should the controlling station so desire, to " call " orally any extra observations which may be of particular interest.

A further advantage of which the selecting device is capable is that its signal could be used to operate a wireless transmitter in lieu of a morse key. By this means a " sferic " network could be controlled in a remote area without the need either for installing an expensive land-line communications system, or for resorting to radio-telephony with its inherent limitations of range. The bearings of the flashes selected by the " pipper " could be transmitted to the controlling station by any available means of communication.

Two sets of the selecting equipment have now been built at an estimated cost each of about £5 for components. One is in routine operation at the new Meteorological Office " sferic " station at Hemsby, near Yarmouth, which has now taken over from Dunstable the task of selecting the lightning flashes to be observed. The second is retained at Dunstable, and is used for monitoring the work of the network and for general investigation purposes.

THE PROLONGED UNPLEASANT WEATHER OF 1950–51

By J. GLASSPOOLE, Ph.D.

The winter of 1950–51 was unusually cold and wet. It followed a wet autumn and wet summer, while the spring of 1951 was also very wet with temperatures below the average, so that the run of unpleasant weather was unusually prolonged. Generally wet weather set in with July 1950, and the monthly values of temperature, rainfall and sunshine from July 1950 to May 1951 are therefore given below.

TABLE I—MONTHLY VALUES OF TEMPERATURE, RAINFALL AND SUNSHINE FROM JULY 1950 TO MAY 1951

	ENGLAND AND WALES					SCOTLAND					NORTHERN IRELAND			
	Temperature		Rainfall		Sunshine	Temperature		Rainfall		Sunshine	Temperature	Rainfall		Sunshine
	Mean at M.S.L.	Difference from average	Amount	Percentage of average	Percentage of average	Mean at M.S.L.	Difference from average	Amount	Percentage of average	Percentage of average	Difference from average	Amount	Percentage of average	Percentage of average
	°F.	°F.	in.	%	%	°F.	°F.	in.	%	%	°F.	in.	%	%
1950														
July	61·5	+0·4	3·9	137	100	58·4	+0·6	5·0	133	113	+0·1	6·5	191	92
Aug.	61·2	+0·3	5·1	147	99	58·1	+1·0	5·2	115	116	−0·2	5·6	135	95
Sept.	56·5	−0·5	5·0	196	79	52·6	−0·5	10·3	257	87	−0·5	7·7	256	82
Oct.	50·9	0·0	1·7	44	100	48·2	+0·2	4·8	98	98	+0·3	3·9	108	98
Nov.	43·7	−0·4	6·0	172	95	40·5	−1·7	5·5	103	117	−2·2	3·0	79	122
Dec.	35·9	−5·6	3·0	76	102	34·4	−5·5	3·5	60	120	−5·8	4·0	97	88
1951														
Jan.	40·0	−0·5	3·8	127	93	37·5	−1·9	6·3	130	104	−1·7	3·7	112	121
Feb.	39·7	−0·9	4·8	186	96	37·5	−2·1	4·3	103	96	−3·3	3·4	113	120
Mar.	40·8	−2·1	4·7	174	83	38·3	−2·7	3·9	95	82	−2·0	2·9	97	87
April	45·3	−1·3	2·9	135	125	41·8	−2·4	4·5	150	114	−1·6	1·8	71	111
May	51·0	−2·2	3·2	140	88	48·1	−1·5	1·9	63	124	−2·1	1·9	72	114

Temperature.—The mean temperature over Great Britain and Northern Ireland was below the average in September 1950 and again for seven consecutive months from November 1950 to May 1951. This long spell of cold months was trying, not only because of the associated wet weather, but also because it followed a long run of relatively warm months. Over England and Wales the 15 consecutive months June 1949 to August 1950 all had above the average temperature. Indeed over both England and Wales, and Scotland during the 24 months ending August 1950 the temperature of every month but two had exceeded the average.

December 1950 stands out as the coldest December over the British Isles as a whole since 1890, and in Scotland probably since 1886. During the present century there have been only six colder months over England and Wales, four Januaries and two Februaries, and over Scotland only three Januaries and one February. In addition to the outstandingly cold December, the following three months were each colder than usual, giving a long spell of wintry weather. The spring months continued to be colder than usual, but temperatures rose in places in both April and May to well over 60°F.

Table II gives a comparison of the temperatures recorded from September 1950 to May 1951 with those of other similar cold periods, the data being arranged in seasons.

This shows that the cold weather of 1950–51 was by no means unprecedented, although it persisted for three seasons.

TABLE II—DIFFERENCE FROM THE AVERAGE MEAN TEMPERATURE OVER ENGLAND AND WALES DURING RECENT COLD PERIODS

	Autumn September–November	Winter December–February	Spring March–May
		degrees Fahrenheit	
1950–51	−0·4	−2·2	−2·0
1946–47	+1·4	−5·3	+0·2
1940–41	0·0	−2·9	−2·3
1923–24	−2·2	−0·4	−1·5
1916–17	+0·4	−4·6	−2·2

Rainfall.—Over England and Wales the rainfall exceeded the average in nine out of the eleven months, over Scotland in seven months and over Northern Ireland in six months. While the run of consecutive wet months is by no means unprecedented, some of the months were outstandingly wet. September 1950 was the wettest September over Great Britain and Northern Ireland since 1869 except for that of 1918. February 1951 was the wettest February on record over part of south-east England, including the London area. The total rainfall of July to September 1950 over Great Britain exceeded that of any similar period since 1869, due mainly to the large amounts recorded in Scotland. The rainfall of January to March 1951 was more remarkable over England and Wales, where it exceeded that of any similar period since 1869 apart from that of 1937.

Sunshine.—The general values for sunshine show that whereas over England and Wales the weather persisted generally duller than usual until the welcome sunshine of April, over Scotland the dull weather prevailed only in September and October 1950 and February and March 1951. Over Northern Ireland the main dull period was restricted to the period July–October 1950.

The weather of 1950–51 was unusual therefore in that the run of wet months was long sustained, while at the same time cold weather also prevailed. The wet September of 1950 over Scotland, the wet February of 1951 over England and Wales, and the widespread cold December of 1950 were outstanding.

WIND RECORDING INSTRUMENTS FOR USE NEAR THE SITE OF THE PROPOSED SUSPENSION BRIDGE OVER THE SEVERN

By G. E. W. HARTLEY, M.A.

In April 1949 the Meteorological Office was asked by the Ministry of Transport to provide instruments for recording the speed, horizontal direction and vertical inclination of the wind at various points across the span of an existing bridge over the Severn at Sharpness, which is not far from the site of the proposed new bridge near Chepstow.

The object of these measurements was to provide data for making wind-tunnel tests on a model of the bridge.* Experience on other suspension bridges has shown that a sustained wind inclined to the horizontal may set up movements in the bridge which may build up until failure occurs; and it was hoped that these measurements would show whether such inclined winds do occur and persist.

The scheme first suggested was to have two pressure-tube anemographs recording in small huts on the bridge, and four special wind vanes which would

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*FRAZER, R. A.; The Severn Bridge aerodynamic research. *Nature, London*, **163**, 1949, p. 7.

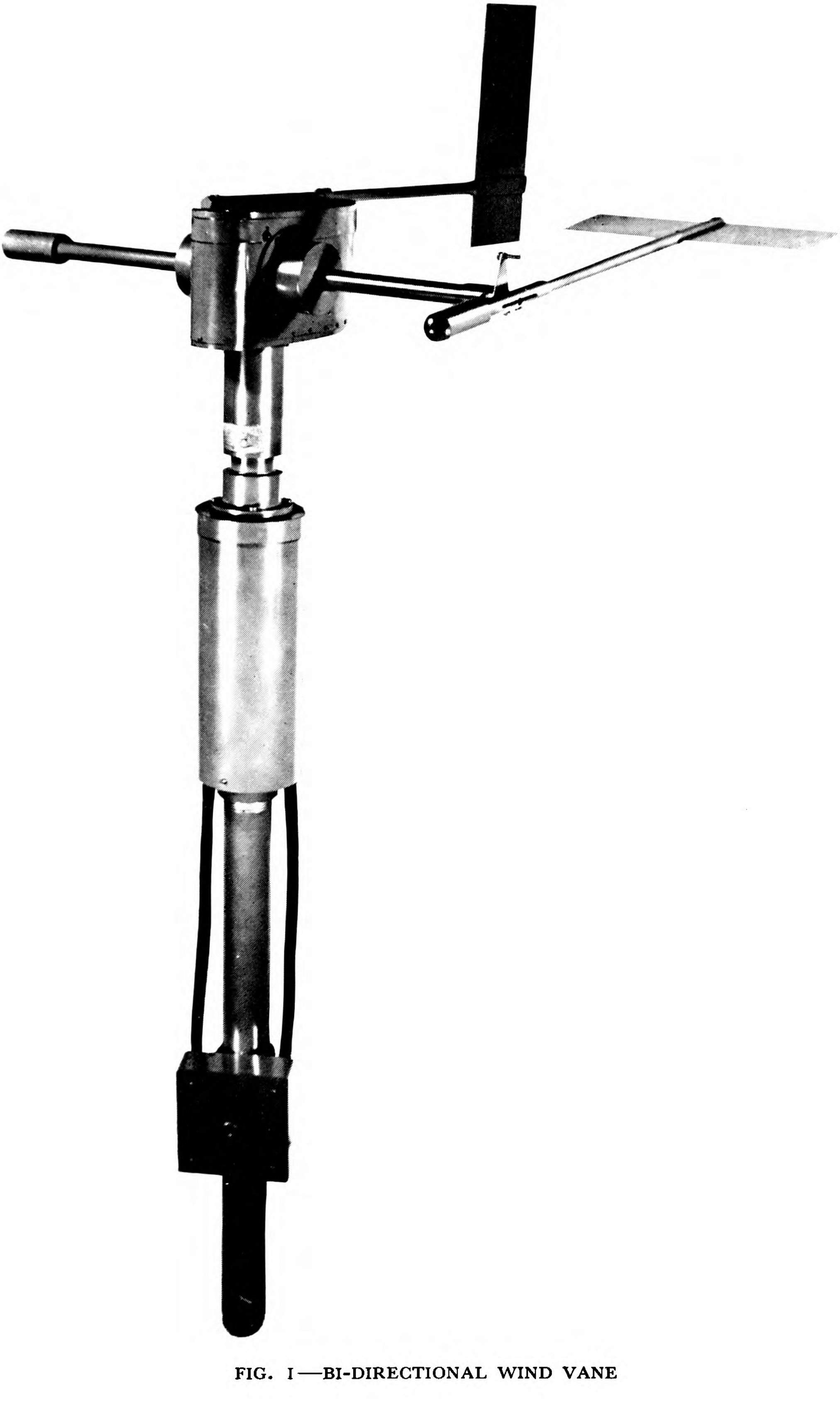


FIG. I—BI-DIRECTIONAL WIND VANE

To face p. 285]

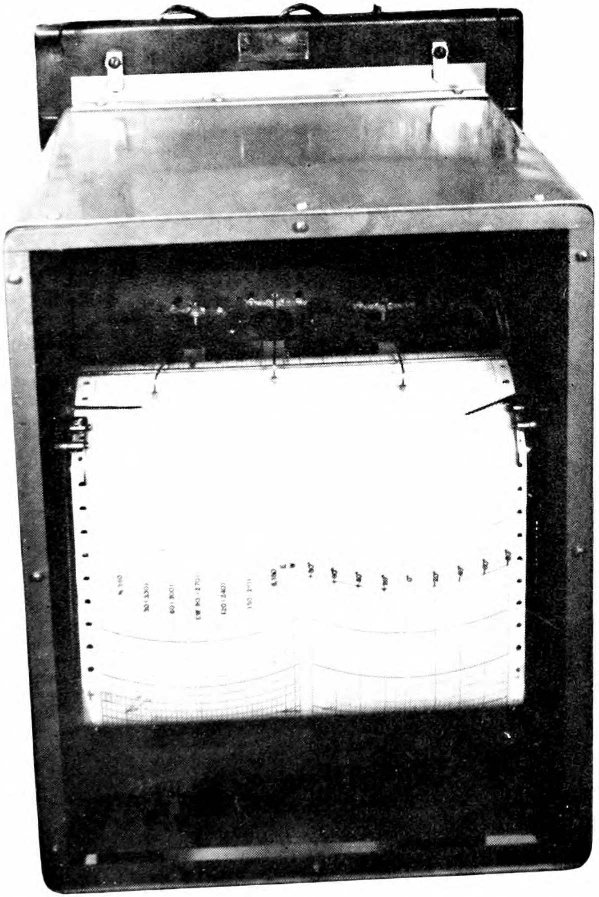


FIG. 3—WIND DIRECTION RECORDER

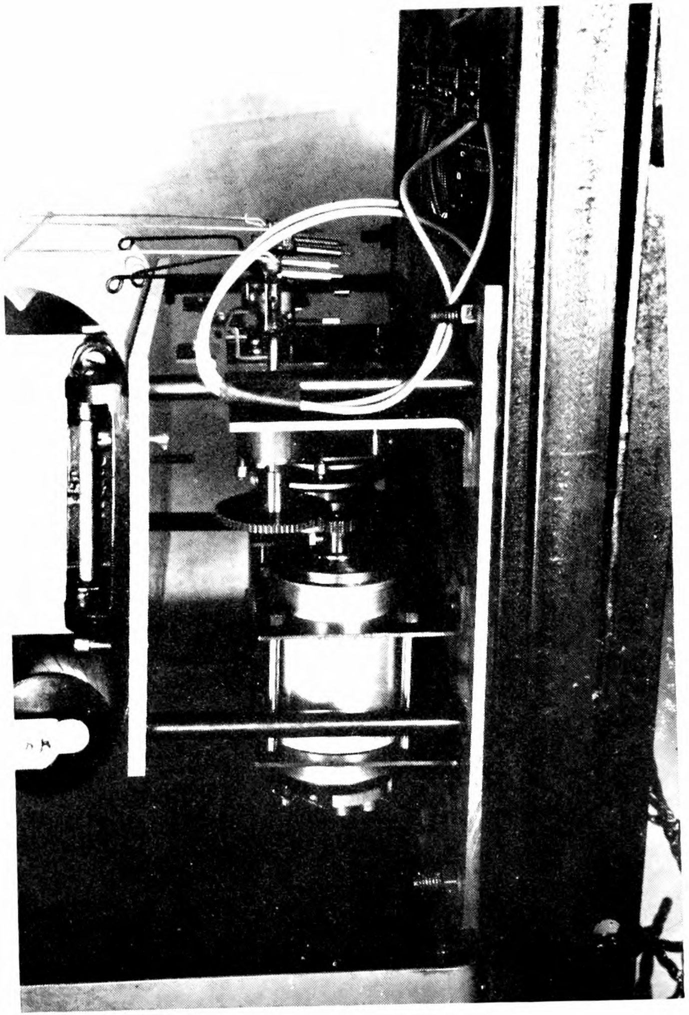


FIG. 4—MECHANISM OF WIND-DIRECTION RECORDER

record inclination of the wind on a standard daily clock drum carried in a housing forming part of the vane; this scheme was subsequently abandoned because of the difficulty of reconciling accessibility (for chart changing) with good exposure; and it was decided to use the magslip self-synchronous a.c. system of remote transmission for both wind directions, and to use recording cup-generator anemometers for speed. There would be four positions across the span of the Sharpness Bridge, at each of which would be a bi-directional transmitting wind vane, and a cup-generator anemometer, all connected through wiring to recorders grouped together in a hut at one end of the bridge. If the necessary electric power was not available at the site, this would be generated by the steam power used to operate the swing span of the bridge when available, and by stand-by petrol electric generators when the steam power was not available.

The bi-directional vane as first designed is shown in Fig. 1 (facing p. 284) and also diagrammatically in Fig. 2. A wind vane A is pivoted on a horizontal spindle B enclosed in a tube C projecting sideways from a housing D, and coupled to a type 10638 magslip transmitter X inside the housing, which is itself mounted on a hollow vertical spindle E. Another vane F to the rear of the housing keeps the whole apparatus pointing to wind; the lateral drag of the horizontally pivoted vane is balanced by the arm G projecting from the opposite side of the housing. A second magslip transmitter Y coupled to the vertical spindle transmits horizontal wind direction. The wires from the magslip X are brought down inside the hollow spindle to slip rings and brushes H. The whole transmitting system is enclosed in a weather-proof housing.

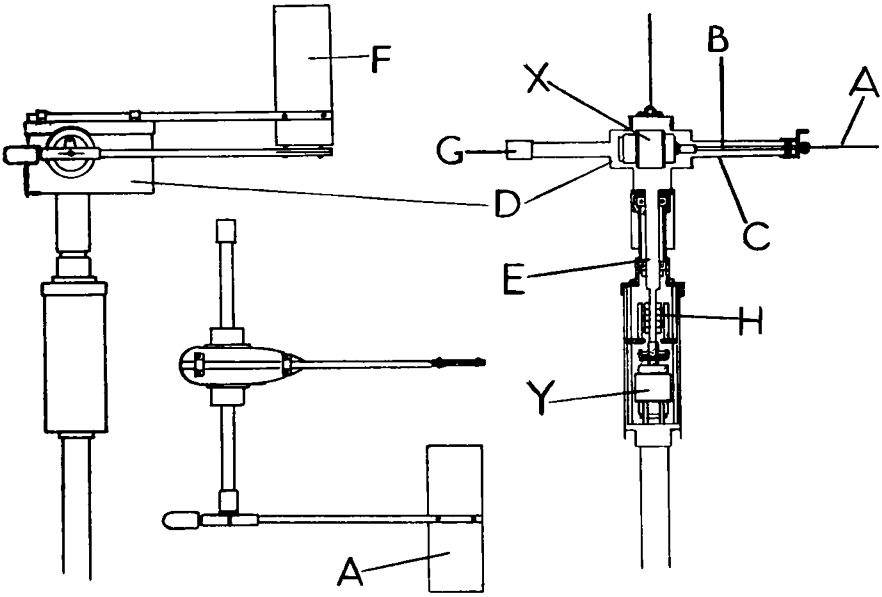


FIG. 2—PLAN ELEVATION AND SECTION OF BI-DIRECTIONAL WIND VANE

The wind-direction recorder is shown in Figs. 3 and 4 (opposite) and consists of a board on which are mounted the two direction receiving magslips. The horizontal-direction magslip carries on its spindle two cams; roller-bearing cam followers engaging with these cams carry on their axes the stirrups which hold the recording pens. The upper cam is so shaped that as it turns through 360° the pen moves from one side of the chart to the other and back again. The chart is marked with N. on the left side, S. on the right side, and both E. and W. at the centre; and the pen is at the same position on the chart for east as for west. The lower cam operates a second pen close to the right side of the chart, and is so shaped that the pen is in one of two positions, one position indicating that the other pen is in the west quadrant, the other in the east quadrant. The scale is 3 in. to 180°. When the wind direction is changing about north or south, there may be some doubt whether the record is on the east or west side; but for this particular investigation a time scale of 12 in./hr. is used which helps to lessen this difficulty; and horizontal direction is not so important as inclination and horizontal speed. The vertical-inclination magslip drives its pen spindle through reduction gearing, so that 4 in. on the chart represents 160° of vane movement, i.e. ±80° to the horizontal. The strip chart mechanism is mounted on a plate carried on pillars in front of the two magslips. Fig. 4 shows the cams and gears and part of the chart mechanism.

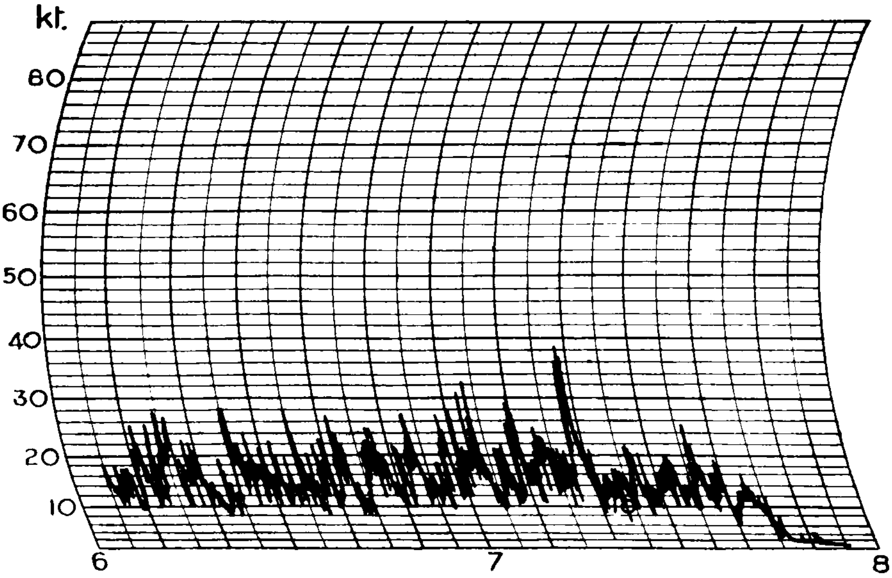


FIG. 5—WIND SPEED RECORD

The pens consist of small diameter tubes with a fine writing nozzle at one end, the other end dipping in an ink reservoir. Ink flows by capillary action, not by siphon. Specimen charts for wind speed and direction are shown in Figs. 5 and 6. In Fig. 6 the wind direction is shown by the upper trace and the vertical inclination by the lower trace.

Unfortunately owing to delay in delivery of the direction-recording chart mechanisms the Sharpness installation is not, at the time of writing, yet in operation; but one complete instrument has been in use at Beachley since January 1951; it is mounted on a 100-ft. steel mast near to an existing pressure-tube anemograph. The results are being examined by the Severn Bridge engineers, but this instrument is being used mainly to find out what defects exist and what modifications are necessary.

As a result of this preliminary trial the wind-direction recording gear is being modified for the Sharpness instruments. The engineers are not interested in changes of vertical inclination lasting only a few seconds; but they are interested when such changes persist over several minutes. It is therefore desirable for the inclination vane not to respond to momentary changes of inclination, but to record any change which persists for, say, more than half a minute. The method to be used was suggested by Dr. Frith; the inclination vane is constructed as in Fig. 7; a ring of polythene tubing is carried on horizontal and vertical spokes, the horizontal spokes carrying the fin and balance weight. At the top of the ring the bore is constricted by a fitting having an adjustable opening. The ring is about one third filled with mercury, the whole assembly being accurately balanced before the mercury is introduced. When the vane is subjected to a change of wind inclination, the fin attempts to turn the vane to the appropriate direction; but the weight of mercury in the lower part of the ring resists this movement as the mercury can only move round in the ring as fast as it can push the air through the constriction. If however the inclination of the wind persists long enough, the mercury will eventually displace enough air to enable it to take up a new position, and the vane will now take an inclined position until a further persistent change of wind inclination moves it again. Thus the response of the vane may be varied by adjusting the size of the constriction.

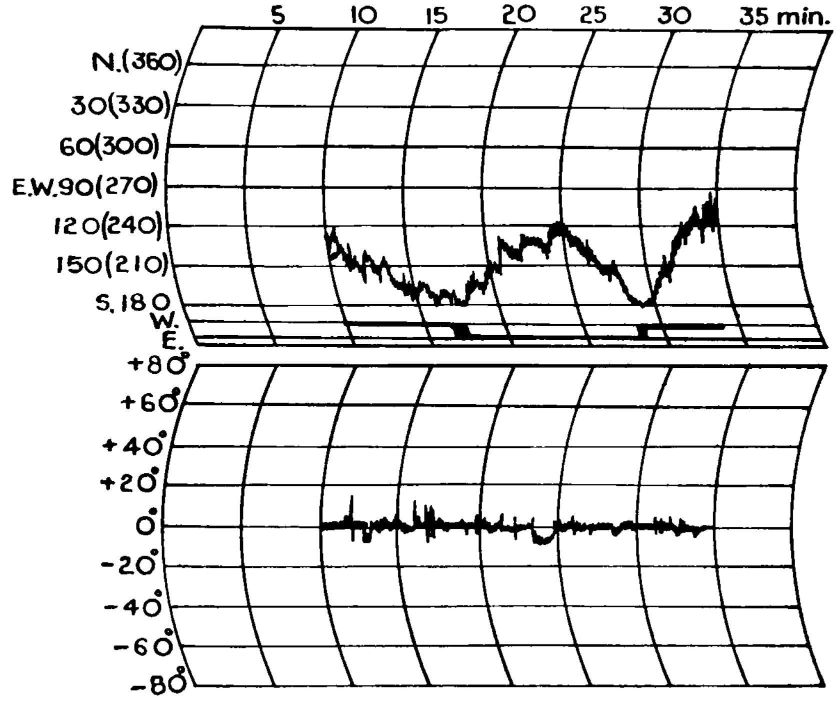


FIG. 6—WIND-DIRECTION RECORD

In the vane at present in use the horizontal-direction vane has been found not to exert enough leverage to turn at low wind speeds, and it is being enlarged and lengthened.

Another defect revealed by trial has been a zero change of the recording pen, due to the stirrup on which the pen is mounted slipping on its axis. Means of checking whether this has occurred are being provided by fitting to the spindle of the receiving magslip an indicator disc fixed relative to the spindle; a mark on this disc is set to come opposite to a fixed mark when the vane inclination is zero, and the chart stirrup and pen can be set to read zero when the two marks coincide; the pen can be adjusted if it does not read zero when checked in this way.

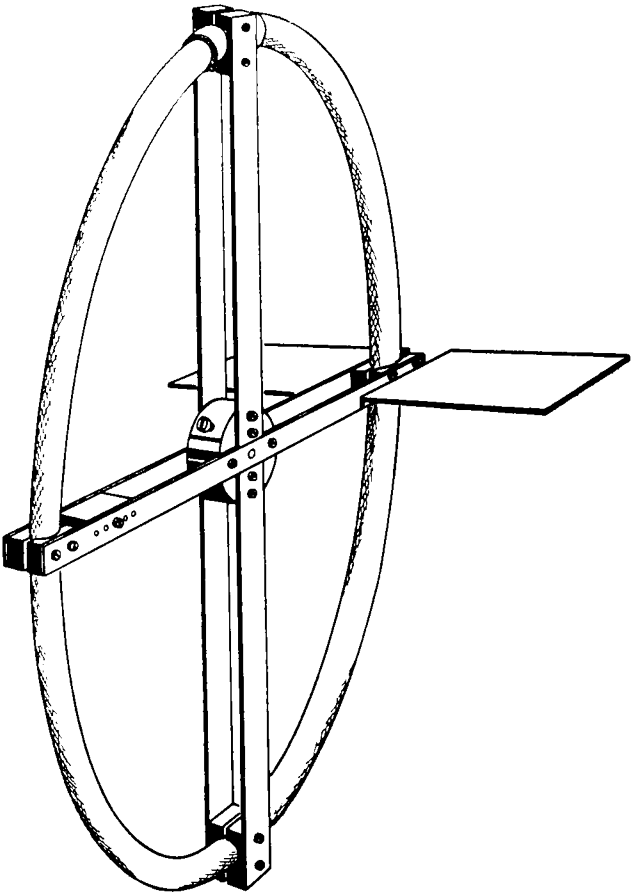


FIG. 7—INCLINATION VANE WITH RING DAMPER

A further modification is to alter the gear ratio of the inclination receiving magslip to give a larger inclination scale which is now to be ±40° instead of ±80°, and to fit stops to the inclination vane to limit its movement to ±40°.

KATABATIC WIND AT DRIFFIELD

By R. H. ELDRIDGE, B.Sc.

The geographical factor leading to the Driffield katabatic wind is the presence of the Yorkshire Wolds. This low range of hills is shown in Fig. 1, the distance of the top of the ridge from the airfield varying from 11 miles in the west to 6–8 miles in the north. The highest parts of the ridge lie west to west-north-west from the airfield (itself one mile west-south-west of Driffield) and are about 700 ft. above the airfield level. The slope is generally fairly uniform. There are two very different types of soil in the area, and the line between the two (shown on the map) follows roughly the 150-ft. contour. South and east of the line the soil is glacial drift, mainly fairly heavy, but with patches of lighter drift; north and west of the line the soil is " wold ", with chalk as the underlying rock. This soil varies in texture but is not heavy. The chalk drains naturally and there is no need for the ditches and drain pipes which are so very necessary on the glacial drift from the wolds to the sea,

The eye observations used in this paper were taken from the balcony of the meteorological office on the headquarters building, R.A.F. Driffield, 25 ft.

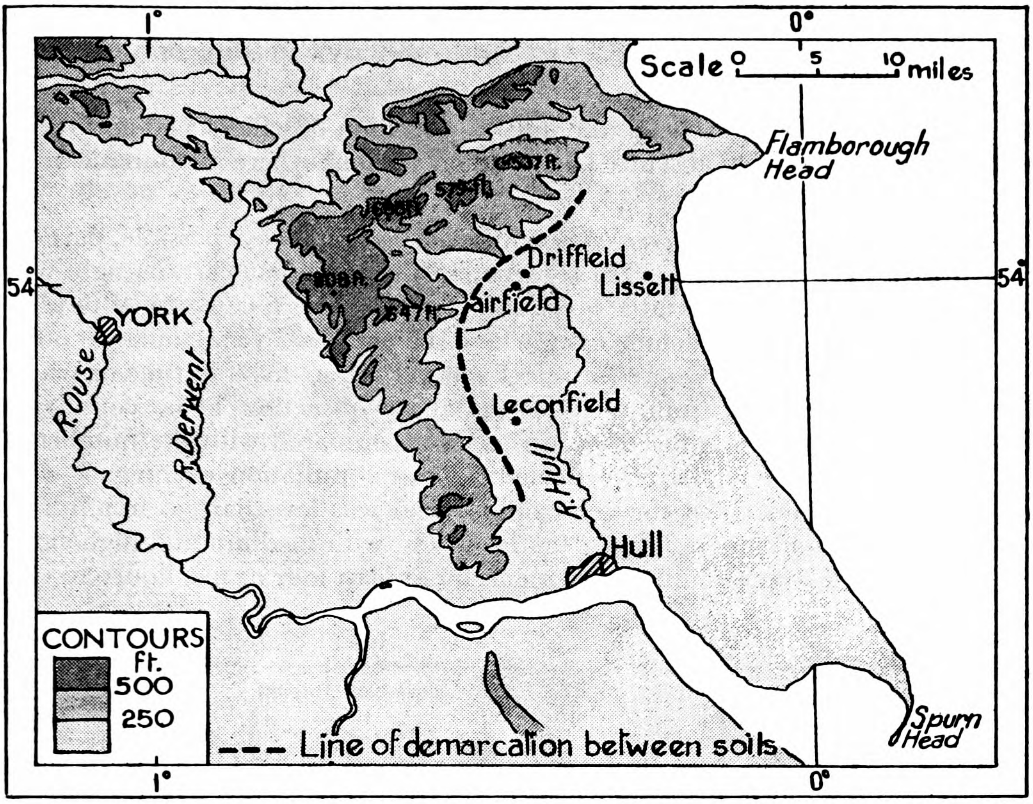

1°
0°
Scale 0 5 10 miles
Flamborough Head
Driffield
Lissett
Airfield
54°
54°
YORK
R. Ouse
R. Derwent
Leconfield
R. Hull
Hull
CONTOURS
Ft.
500
250
--- Line of demarcation between soils
Spurn Head
1°
0°

FIG. 1—YORKSHIRE WOLDS, EAST RIDING OF YORKSHIRE

above the ground. Temperatures were taken from the screen on the ground near by. Wind direction and wind speed were taken from a vane and cup anemometer on the headquarters building at a height of about 45 ft. above the ground. Driffield airfield is well exposed to any flow of air from the north-west, only isolated clumps of trees offering any hindrance. Between the meteorological office and the airfield, buildings, varying in size from small huts to hangars, extend in the north-west quadrant from the meteorological office for a distance varying between 300 and 600 yd.

The records of the six months from March to August 1943, inclusive, have been thoroughly searched for occasions of katabatic winds. The following data have been extracted from the records:—

(i) Time of start of wind
(ii) Duration of wind
(iii) Strength of wind
(iv) Component of geostrophic wind in direction of " pure " wind
(v) Rate of fall of temperature before onset of wind
(vi) Indication of lapse rate of temperature in the vertical.

Some unusual variations in surface temperature, humidity, visibility and local cloud effects have also been noted.

The effect of the wind may be considered in two main groups:—

(*a*) A " pure " wind, where the pressure gradient taken from a chart of sea-level pressure is either non-existent or opposed to the natural direction of the wind. This wind is from WNW., Beaufort force 1 or 2. At only one hour during the six months dealt with in this paper was force 3 recorded, this being just 8 m.p.h.

(*b*) A wind, similar in speed to that expected from the pressure gradient, but considerably different (i.e. west-north-westerly) in direction. This is generally of force 1 or 2.

On one occasion (March 14) the diurnal variation of wind speed and direction was almost entirely absent. The occasion was one where a katabatic wind was probable.

Analysis of data.—*Frequency of occurrence.*—It is not always possible, particuarly in a retrospective analysis, to say whether the wind on a certain night was or was not katabatic. The table given therefore contains a category of possible katabatic effects. These include cases where the wind was very similar at other Yorkshire stations, some where the effect was very short-lived in time or where the wind was too far from the pure katabatic direction to be considered as such a wind. The number of occurrencies is compared with the number of occasions when one might be expected. These "radiation evenings" were defined as occasions when the geostrophic wind was less than 30 m.p.h. and when the low cloud amount was 4 tenths or less, with medium and high cloud taken into consideration in the assessment, for at least four or five hours around sunset.

	Mar.	Apr.	May	June	July	Aug.	Total
			number of occasions				
Radiation evenings	17	10	18	12	14	11	82
Katabatic winds	6	3	6	7	8	5	35
Possible katabatic wind	4	4	4	2	2	2	18

11 of the 35 occasions were pure effects, but this small proportion is largely because of the generally prevailing south-westerly winds.

Time of onset.—The time of start of the wind, expressed as hours after sunset, is shown below.

	Time from sunset to start of wind (hr.)						Mean time
	1	2	3	4	5	6	
			number of occasions				hr.
Pure wind	...	2	5	2	1	1	3·5
Aided wind	3	5	9	3	3	1	3·0
Total	3	7	14	5	4	2	3·1

As the winds were generally noted only at the normal hourly observations these average figures are probably each too large by about ½ hr. Where the wind showed as a marked change in direction, as was frequently the case, this was generally complete between two hourly observations. There was rarely a gradual change with an increasing component from a west-north-west direction as would be expected.

Duration.—Of the eleven occasions of pure katabatic wind, seven lasted till dawn or beyond (by one or two hours), in three the wind stopped one or two hours before dawn, and in one, after only one hour; this last occasion (March 14) is referred to below. Of the 24 aided occasions 18 lasted till dawn or beyond, though on some of these occasions the wind was continuous with the normal day-time surface wind.

Vertical and horizontal structure.—Very little direct information could be obtained on the vertical structure. The only occasions when a pilot balloon would give useful information would be when the normal pressure gradient was almost opposite to the katabatic direction, and such occasions were few. Only one ascent was made in a katabatic wind and the balloon veered so rapidly that no theodolite readings could be obtained. But it seemed that little of the effect extended above 200–300 ft. Indirect evidence from low-stratus formation on March 14, referred to later, suggests that on this occasion the wind was certainly effective to 200–300 ft. Katabatic winds have been experienced occasionally at Lissett and Leconfield, but of force 1 only.

Rate of fall of temperature.—The rate of fall of the dry-bulb screen temperature at Driffield for the three hours before the start of the wind was obtained for each occasion, with the following results.

	Rate of fall of temperature (°F./hr.)			
	0·0–0·9	1·0–1·9	2·0–2·9	3·0–3·9
		number of occasions		
Pure	1	3	3	4
Aided	1	7	12	4
Total	2	10	15	8

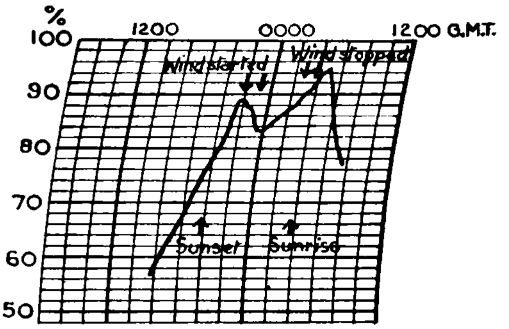
Geostrophic wind.—The component of the geostrophic wind from WNW. was obtained from three-hourly charts. In some cases of light gradient the Spurn-Head surface wind was taken as being a representative sea-surface wind, and this enabled significant errors to be avoided. On only one occasion of pure katabatic wind was the component opposing the wind greater than 10 m.p.h. (18 m.p.h.). Aided winds occurred with all values of the components up to 20 m.p.h., and one of 25 m.p.h.

Vertical temperature distribution.—The temperature distribution in the vertical could obviously not be obtained very accurately. It was, however, felt worth while to attempt some estimation. The figures below give the change in temperature from the surface to 2,000 ft. at the time of start of the wind at Driffield. These have been derived from 950 mb. temperatures interpolated from all available radio-sonde and aircraft ascents.

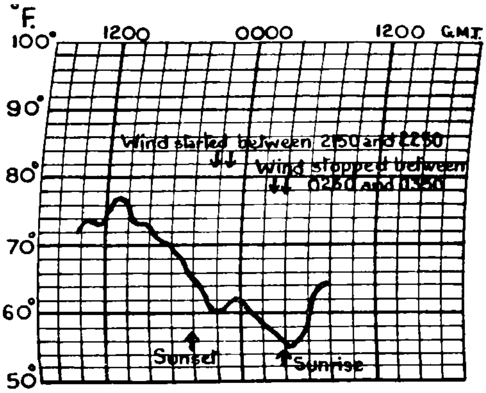
	Temperature difference (°F.) at the start of the wind (2,000 ft. minus surface)							
	−6, −5	−4, −3	−2, −1	0, 1	2, 3	4, 5	6, 7	8, 9
				number of occasions				
Pure katabatic	←1 (indeterminate)→			1	2	2	4	1
Aided katabatic	1	5	2	6	7	2	...	1

For some of the occasions interpolations could be made from actual 1,000-ft. temperatures obtained from soundings though naturally less reliance could be placed upon these figures due to local influences. Thirteen of these values were obtained and varied from a lapse of 1°F. to an inversion of 14°F. at the start of the wind.

Effects of wind.—*Surface temperature and humidity.*—On some occasions inspection of the thermograph traces showed either a rise in dry-bulb temperature or a decrease in the rate of fall of temperature shortly after the start of the wind. On one or two occasions there was a fall in the humidity shown on the hygrograph trace. Newnham[1] noticed that this occurred with the katabatic wind at Benson, and pointed out that the temperature rise was due to the stirring up of the lower layers which were previously stably stratified. With the reservation already noted about upper air temperatures in this paper it may be stated that the occasions (about ten) which showed this temperature effect all had a marked increase of temperature to 1,000 ft. The decrease in relative humidity at screen level is of course not a necessary result of this mixing. The two effects are well shown on the traces for July 28, reproduced below. At 2100 and 2200 G.M.T. there was no wind but by 2300 the katabatic wind was blowing from WNW., force 2, and continued between force 1 and 3 for five hours. On other occasions the effect appeared as a check to the cooling, displacing the trace one, two or three hours. During this period of six months there were no cases where the wind brought in distinctly cooler air, but it should be pointed out that certain days of exceptional cooling in October and November 1948 appear to have been connected with the wind.



RELATIVE HUMIDITY FOR JULY 28–29, 1943



DRY-BULB TEMPERATURE FOR JULY 28–29, 1943

Visibility.—It is considered that the wind helps to give better visibility at Driffield than at some other airfields in Yorkshire. This is attributed by some to actual deflection of smoke-laden air from the industrial areas to the south-west and this probably does play some part. But it is also very probable that the temperature effect described above is important in delaying cooling and consequent condensation.

Low cloud.—On March 14 the katabatic wind, following a day-time sea breeze, appeared to hasten the formation of low stratus at 200–300 ft.

Consideration of results.—The data available are very inadequate for anything approaching a full analysis from which an understanding of the mechanism could be obtained. The geostrophic wind is the only guide to the wind shear in the lowest layers as is the interpolated 1,000 or 2,000-ft. temperature, together with that at the surface, the only available guide to the thermal structure. Observations at Driffield necessarily show the effect of the wind some time after it has started and away from the actual hillside above which the energy of the wind is generated. The analysis has also excluded certain occasions when the wind was west-south-westerly or north-west to north-north-westerly which might well have been katabatic, and one or two occasions where the wind blew for a very short time only and had been preceded by a small rate of fall of temperature (of the order of 1°F./hr.). These may well have been significant and are included in the " possible " category.

Early cessation of the wind may well be accounted for in some cases by the loss of energy involved in stirring the stably stratified air. Cornford[2] and Heywood[3] both comment that the katabatic winds they observed appeared to cease by the time a large inversion had been set up.

No hard forecasting rule can be produced from the analysis, but with a geostrophic gradient of 10 m.p.h. or less (whatever the direction), less than a quarter of the sky covered for three or four hours after sunset and a high day-maximum temperature, a katabatic wind is almost certain. There is a good chance of it with gradients up to 20 m.p.h. It may be expected to start about 2–3 hr. after sunset and last till about dawn.

Acknowledgement.—I am indebted to the County Agricultural Officer, East Riding of Yorkshire, for the information on soils.

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1. NEWNHAM, E. V.; Notes on examples of katabatic wind in the valley of the upper Thames at the aerological observatory of the Meteorological Office at Benson, Oxon. *Prof. Notes met. Off., London,* **1,** No. 2, 1918.
2. CORNFORD, C. E.; Katabatic winds and the prevention of frost damage. *Quart. J. R. met. Soc., London,* **64,** 1938, p. 553.
3. HEYWOOD, G. S. P.; Katabatic winds in a valley. *Quart. J. R. met. Soc., London,* **59,** 1933, p. 47.

OFFICIAL PUBLICATION

The following publication will be issued shortly:—

Annual Report of the Director of the Meteorological Office presented by the Meteorological Committee to the Secretary of State for Air for the year April 1, 1950, to March 31, 1951.

The Report describes the work of the State Meteorological Service. The work covers the meteorological needs of the Royal Air Force, civil aviation, other government departments and public utility corporations, the general public, agriculture, the Merchant Navy and industrial concerns. Services to these bodies have been improved and extended during the year. New meteorological offices have been opened to meet the needs of the expanding R.A.F. For civil aviation, new meteorological broadcasts by radio-telephone have been introduced to conform with changed practices of airline operators. For agriculture, a potato-blight warning system was tried out and proved very successful, and warnings of frost and snow were extended.

The amount of flying at great heights (above 40,000 ft.) is increasing rapidly, and in consequence much investigation of turbulence and on forecasting winds at these levels has been done. Among the many other subjects of research mentioned in the Report are the visibility of airfields from the air in poor meteorological conditions, methods of forecasting for comparatively long periods, the physical conditions in clouds, especially in relation to gust structure and the icing of aircraft. In these last investigations considerable use has been made of radar. Development work has also been done on a number of new instruments, in particular the radar theodolite, for the measurement of upper winds.

The geophysical observatories at Kew, Lerwick and Eskdalemuir have continued to make observations and automatic records of meteorological elements, terrestrial magnetism, solar radiation, atmospheric electricity and seismic movements.

The responsibilities of the Meteorological Office overseas have been slightly reduced by the handing over to local governments of certain meteorological services in the Sudan, British Somaliland, Tripolitania and (to a limited extent) in Germany.

Senior members of the staff have attended meetings of the International Meteorological Organization and its successor, the World Meteorological Organization, and the International Civil Aviation Organization.

METEOROLOGICAL RESEARCH COMMITTEE

The sixteenth meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on July 5, 1951. The main discussion was on an interesting essay by Mr. C. K. M. Douglas on the evolution of forecasting in the British Isles in the twentieth century[1]. Applications of recent lines of forecasting research were also considered in this connexion.

A detailed study by Mr. J. S. Sawyer[2] of the rainfall of two selected synoptic situations, a secondary depression and a warm front respectively, was discussed with interest. Other papers considered were a note on the usefulness of forecasts by Mr. A. F. Crossley[3], and a report on the accuracy of wind forecasts at altitudes of 30,000 ft. over Egypt by Mr. C. S. Durst[4].

The seventeenth meeting of the the Physical Sub-Committee of the Meteorological Research Committee was held on July 18, 1951.

Two papers by Mr. E. Knighting[5,6] were discussed. The first of these papers deals with the equation of turbulent diffusion in the atmosphere and sets out to give an account of the solution of this equation under the boundary conditions which are normally met with in meteorological problems. The second paper gives a solution of the power-law diffusion equation for the case in which the surface variation is of the form of a sine wave and offers some criticisms of the method hitherto used for the estimation of the index in the power law.

A paper by Mr. Bannon[7] dealing with an analysis of occasions of turbulence at high altitudes was also discussed.

A report[8] on the measurement of temperature fluctuations over very short periods of time and at high altitudes was presented by Mr. Grant.

[1] *Met. Res. Pap., London,* No. 654, 1951.
[2] *Met. Res. Pap., London,* No. 650, 1951.
[3] *Met. Res. Pap., London,* No. 653, 1951.
[4] *Met. Res. Pap., London,* No. 655, 1951.
[5] *Met. Res. Pap., London,* No. 598, 1951
[6] *Met. Res. Pap., London,* No. 609, 1951
[7] *Met. Res. Pap., London,* No. 660, 1951
[8] *Met. Res. Pap., London,* No. 658, 1951

LETTERS TO THE EDITOR

Effect of shelter hedges on mean temperature

Facing p. 344 of the December 1950 number of the *Meteorological Magazine* is a fine aerial photograph of Eskdalemuir Observatory, showing a substantial shelter belt of coniferous trees enclosing the area. It would be of considerable interest, especially from the agricultural point of view, to know just how shelter of this kind effects the local climate, for example, the daily range of temperature in summer.

Owing to its situation far from human interference, and to the high accuracy of the recording, the temperatures observed at Eskdalemuir are particularly suitable for indicating long-period fluctuations of the average. In order to examine the possible effect of the growth of the surrounding trees on the overall mean temperature, the following table compares those observed at Eskdalemuir with two very reliable records from the same region. For various reasons it is thought that the values recorded at Blackfort Hill, Edinburgh, and those reduced by G. Manley for Lancashire, have not been affected by urban development during the period in question.

	20-year periods 1911–30	 1921–40	 1931–50
		degrees Fahrenheit	
Average mean temperature	44·30	44·70	45·00
Eskdalemuir minus Edinburgh	−2·55	−2·58	−2·66
Eskdalemuir minus Lancashire	−4·08	−3·92	−3·95
Average difference	−3·31	−3·25	−3·30

It would appear from these figures that the increasing height and density of the shelter belt at Eskdalemuir has had no significant effect on the overall mean temperature recorded there. Its effect on the daily range is a different matter.

The appreciable rise of mean temperature shown by the figures is interesting, but the period is too short to indicate how much of it is due to a temporary fluctuation. Manley's reductions for Lancashire, covering nearly two hundred years, suggests that the present century has been exceptional in this respect, earlier periods of rising average being of much shorter duration.

G. S. CALLENDAR

Percuil, Parsonage Road, Horsham, July 6, 1951

Forecasting ground frost

From investigations made at Münster, R. Faust* has proposed the formula

$$T + \frac{D}{2} < 79$$

for the forecasting of ground frost on radiation nights, where T and D are screen temperature and dew point respectively in degrees Fahrenheit at 1400 local time.

The formula has been derived for a lowland station (Münster) and should apply to an average station in fairly level country in the United Kingdom. It is also specified that cloud should be less than 2 tenths and wind speed less than Beaufort force 2 during the cooling period.

TABLE OF VALUES OF $T + D/2$ AND GRASS MINIMUM

Date	$T+\frac{D}{2}$	Grass minimum (next morning)	Date	$T+\frac{D}{2}$	Grass minimum (next morning)
	°F.	°F.		°F.	°F.
12.9.50	86·5	50·9	2.3.51	69·6	25·0
13.10.50	85·9	41·0	15.3.51	69·3	27·0
14.10.50	76·7	35·0	30.3.51	55·5	26·2
24.10.50	74·6	28·0	17.4.51	64·7	30·0
25.10.50	71·7	27·9	23.4.51	82·1	30·0
6.11.50	65·7	24·0	24.4.51	87·7	34·0
17.11.50	65·8	29·0	10.5.51	73·7	28·0
7.12.50	63·5	26·0	4.6.51	86·8	42·0
27.2.51	59·2	25·0	5.6.51	85·7	38·0
28.2.51	61·6	23·0	8.6.51	81·5	35·0

To test the formula all radiation nights at Hullavington were selected since September 1950 which fulfilled these requirements. The values of $T+D/2$ at 1400 G.M.T. and the grass minimum reading for the next morning are shown in the accompanying table and have been plotted against one another in the

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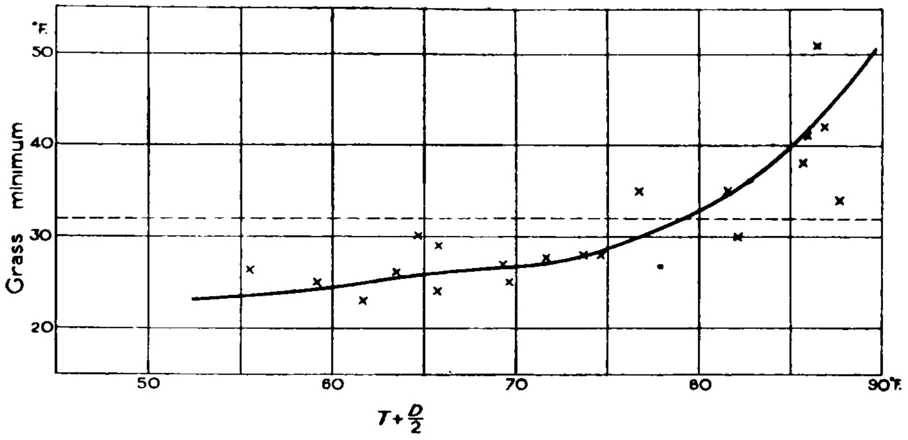
*FAUST, R,; Ein Hilfsmittel zur Nachtfrostvorhersage. *Ann. Met., Hamburg,* **2**, 1949, p. 105.



accompanying graph. The approximate curve of best fit is seen to cross the 32°F. line at about 79. The grouping of points about the line is not very close but no allowance has been made for the possible advection of different air between 1400 and the cooling period The results do appear to indicate that the formula can be used with some degree of confidence.

G. J. JEFFERSON

Hullavington, Chippenham, Wiltshire, June 14, 1951

NOTES AND NEWS

Climatological observations at Greenwich

With the transfer of the Royal Observatory from Greenwich to Herstmonceux Castle, now at an advanced stage, the long series of climatological observations on the Observatory site in Greenwich Park will shortly come to an end.

Climatological observations have been an official part of the work of the Royal Observatory since 1841 when its Meteorological Department was established and regular hourly observations began. Before that date a private record of temperature and rainfall was kept by one of the assistant astronomers, from 1815 onwards, and with the help of these data and of other series of observations from nearby stations it is possible to extend the temperature record back to 1811. The monthly totals of rainfall, adjusted to give a homogeneous series, 1815–1914, were published in *British Rainfall 1915*, pp. 36–7.

In general, however, the data cannot be regarded as homogeneous because of the progressive urbanization of the neighbourhood during the period covered. but this long record is of course of great interest and value for many purposes. The sunshine record, for example, shows the growing effect of London smoke, which eventually became one of the dominant disturbing factors in astronomical work leading to the decision to move the Observatory. The disturbing effects of urban conditions were not entirely on the dark side, however, as another factor was the interference from bright street lighting with long-exposure night-sky photography. As far as magnetic work is concerned, the disturbance resulting from the increasing use of electrical equipment led to the establishment of the alternative site for this work at Abinger in Surrey in 1924.

The complete cessation of climatological records at Greenwich would have been a matter of serious concern to many interested parties, and it is therefore pleasing to be able to report that a very satisfactory alternative arrangement has been made. For various reasons there was no question of continuing the observations on a strictly comparable site in Greenwich Park, and a reconnaissance of the district showed that the next best site was undoubtedly in the grounds of the National Maritime Museum, a few hundred yards away. In fact, though any break in continuity due to a change from a long-established site is much to be regretted, it was expected that a site near the Museum would prove to have the advantage, over the comparatively elevated parkland site, of being more representative of the lower built-up ground which forms the major part of Greenwich and extends beyond the borough along the river.

When the Director of the National Maritime Museum was approached he showed great interest and readily consented to put before his Board of Trustees the proposal to set up within the grounds a small station to be equipped by the Meteorological Office and looked after by Museum Staff. The Board kindly granted their approval of the scheme and thus provided the prospect of continuing the basic observations on a good site for many years to come. The Director and his staff at once co-operated most enthusiastically in the early establishment of the station and observations began on May 1, 1951. All who are interested in climatology will share the appreciation which is felt within the Meteorological Office of the very helpful attitude shown by the Museum Director, and of the considerable effort which was made by his staff in the immediate fulfilment of the plan. An essential part of the plan was to secure, for as long a period as possible, an overlap of observations at the old Observatory site and the new Museum site. In this the Observatory staff who still remain at Greenwich have willingly co-operated, at the expense of personal inconvenience, particularly at week-ends and on public holidays, and after the meteorological observations have ceased to be of much value for purely Observatory purposes. Their full series of observations including hourly values ceased in May 1950, but the standard climatological records are at present still being maintained (August 1951).

As the Royal Observatory was established at Greenwich by Charles II in 1675 for the advancement of the science of navigation and nautical astronomy, it is very fitting, as the Museum Trustees and Director doubtless appreciated, that the continuation of a part of its work, near the original site, should be in the hands of the National Maritime Museum. It is equally appropriate that the Meteorological Office, having shared the fruits of the meteorological work of the Royal Observatory, should now become responsible for the equipment of the new station in the endeavour to prolong the record.

A. BLEASDALE

A Relic of the Royal Observatory, Richmond*

H.M. King George III built Kew Observatory for the purpose of rating his clocks and as a repository for the large collection of philosphical instruments which he and Queen Charlotte had collected, probably at the suggestion of Dr. Demainbray who had been scientific instructor to both before their marriage. It was finished in time for the observation of the transit of Venus JE on ~~July~~ 3, 1769.

When H.M. Queen Victoria decided to give up the Observatory in 1840, the collection was distributed to various interested authorities, the greater part of the scientific instruments being sent to the Curators of the Museum of King's College, London, with a request that the collection should be kept together and also used for instructional purposes.

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*According to the wording of the Catalogue.

The collection has now been lent by King's College to the Science Museum, South Kensington, for an indefinite period. At the suggestion of the authorities of both these institutions a manuscript catalogue relating to the collection, and hitherto located at Kew Observatory, has been made available for permanent preservation with the collection. This catalogue—" The Queen's Catalogue "—was presented by J. Rigaud, a great-grandson of Dr. Demainbray, to the British Association (then in control of Kew Observatory) in 1855. The catalogue, which relates to Queen Charlotte's contribution to the collection, lists 322 instruments (nineteen foolscap pages) and 76 presents received by the Queen from various people (four pages).

The Queen's Catalogue is described in detail in a paper by R. S. Whipple, " An old catalogue and what it tells us of scientific instruments and curios collected by Queen Charlotte and King George III ", published in the *Proceedings of the Optical Convention, London*, 1926, Part II.

The Director of the Science Museum has also in hand a printed account of the whole collection and the present whereabouts of the different parts of it, which will be available shortly.

Meteorological note on the Sudan haboob

In *Notices to Airmen* No. 8/51 dated March 29, 1951, the Sudan Government has brought to the notice of persons engaged in air navigation a meteorological note on the haboobs which occur in the Sudan from May to September. As the meteorological information given in this *Notices to Airmen* is of general interest it is reproduced below by kind permission of the Sudan Government Meteorologist:—

The term " haboob " is a very loose name which has been applied to a duststorm, either associated more or less *in situ* with one or more thunderstorms, or completely dissociated with the thunderstorm activity from which the duststorm is born.

Outrushing cold air from precipitating cloud of the cumulonimbus type may vigorously undercut the much warmer air of its environment, and the resulting violent ascent of air can quickly produce a " wall " of rising and blowing dust in advance of the storm clouds provided the soil surface is very loose. This state of affairs occurs from about late April or May onwards in the Sudan north of about the 13° N. parallel of latitude, and gives rise to the well known Sudan " haboob ".

In the early stages of its development, the duststorm is adjacent to the thunderstorm, but the dust " front " travels much quicker than the storm itself, and, provided the cold air supply and resulting gradient of pressure are maintained, may travel even some hundreds of miles before its energy is spent. It follows that the more vigorous the thunderstorm area, the more vigorous and intense the resulting duststorm. As the summer season progresses, however, the thunderstorm areas advance northwards, and, with the loose surfaces being bound together more firmly as the result of rain, the duststorms progressively become less intense in these areas.

In the Khartoum area the worst duststorms therefore occur early in the season (May and June), when the main thunderstorm activity is well to the south and the soil surface north of the 13°N. parallel initially very dry and loose. Later in the summer, thunderstorms are more prevalent in this area and the associated duststorms are less intense and much shorter-lived, though duststorms may be still severe to the north. Early-season duststorms usually last from 2 to 4 hours and in very exceptional cases much longer. Because they are the result of large-scale thunderstorm activity to the south, they normally occur after dusk. Late-season duststorms may only last some 5 to 15 minutes, and since they are usually directly associated with the thunderstorm(s), normally occur any time after midday.

Normal conditions associated with Sudan "haboobs" are as follows: Visibility is frequently reduced to well below 200 m. and the improvement is relatively slow in the early-season type of duststorm. Surface wind speeds may suddenly increase from zero to 25–40 kt. in a matter of seconds, and some initial gusts have been recorded of 50–60 kt. or above. A slow decrease of wind speed normally occurs after the first 30–60 min. The wind direction is initially from the south-easterly quarter in general, with a slow and steady veer towards the S. or SSW. with time. The dust tops are normally of the order of 2,000–3,000 m., very exceptionally to 3,500 m. or a little above. Turbulence is excessive at first decreasing slowly. Any rain falling through a duststorm improves visibility rapidly.

Phenomenally rapid rise in level of the River Euphrates

We are indebted to the Senior Meteorological Officer, R.A.F. Habbaniya, Iraq, for a note on a phenomenally rapid rise in the level of the River Euphrates in March 1950. The river at Habbaniya rose 8 ft. 6 in. in 48 hr. between March 10 and 12, 1950.

During the winter 1949–50 there were very heavy falls of snow in the Turkish mountains, and the primary cause of the rise in question seems certainly to have been the melting of this snow, assisted by rain falling over the Euphrates watershed in late February and early March 1950.

The river level would not have risen so appreciably in the 48 hr. in question, however, without two other factors operating in the source region of the river, namely rain and warmth; both these factors were in fact present. The weather situations which induced the snow to melt and which provided also additional rainfall were more especially the following:—

(*a*) 0000 G.M.T. February 21–1200 G.M.T. February 22. A low-pressure system over the eastern Mediterranean Sea and Jordania moved east, gave much rain over Turkey and marked rain-shower activity over the Levant, including thunderstorms over Syria.

(*b*) 1200 G.M.T. February 23. A depression over south-west Turkey moved east with much rain and many thunderstorms over the upper reaches of the river; by 0000 G.M.T., February 25, rain and thunder activity had almost ceased, although rain was reported in the Diyarbakir area until 0300 G.M.T. on February 26. This weather situation was complicated by a nearby active depression which was centred over the eastern Black Sea and the Caucasus Mountains and helped to cause an influx of warm air over central and southern Turkey.

(*c*) 0000 G.M.T. March 4. Heavy rain outbreak near Diyarbakir. Later that day, thundery activity over Jordania and Lebanon, and rain over Turkey which occurred intermittently until 0000 G.M.T. March 7.

No such rapid rise took place in the River Euphrates in the spring of 1951. The chief reason for this appears to have been the small amount of snow in the mountains around the source during the winter 1950–51. The crews of Turkish aircraft flying the route Ankara–Diyarbakir–Habbaniya remarked to the meteorological staff at Habbaniya that they have never known so little snow on the mountains.

Radio-telephone station at Great Dun Fell, Cumberland

The Ministry of Civil Aviation has recently installed a chain of twelve radio-telephone stations to provide communication between aircraft flying the new Civil Airways and Air Traffic Centres at Uxbridge, Preston and Prestwick. For technical reasons four of these stations are sited on the tops of mountains.

The photographs (between pp. 300–01) were taken at 1000 on January 16, 1951, during the installation and commissioning of the radio equipment at Great Dun Fell, 2,780 ft. above sea level, in the Pennines 14 miles from Penrith, Cumberland.

The station is the highest permanently manned post in the British Isles, and the road thereto is likewise the highest road, public or private.

The station is built on the site of a hut installed about 1938 by Prof. Gordon Manley for weather observation and a study of the local helm wind. Prof. Manley's experience and advice proved invaluable during the planning stages of this station, and his description of the conditions have been more than borne out.

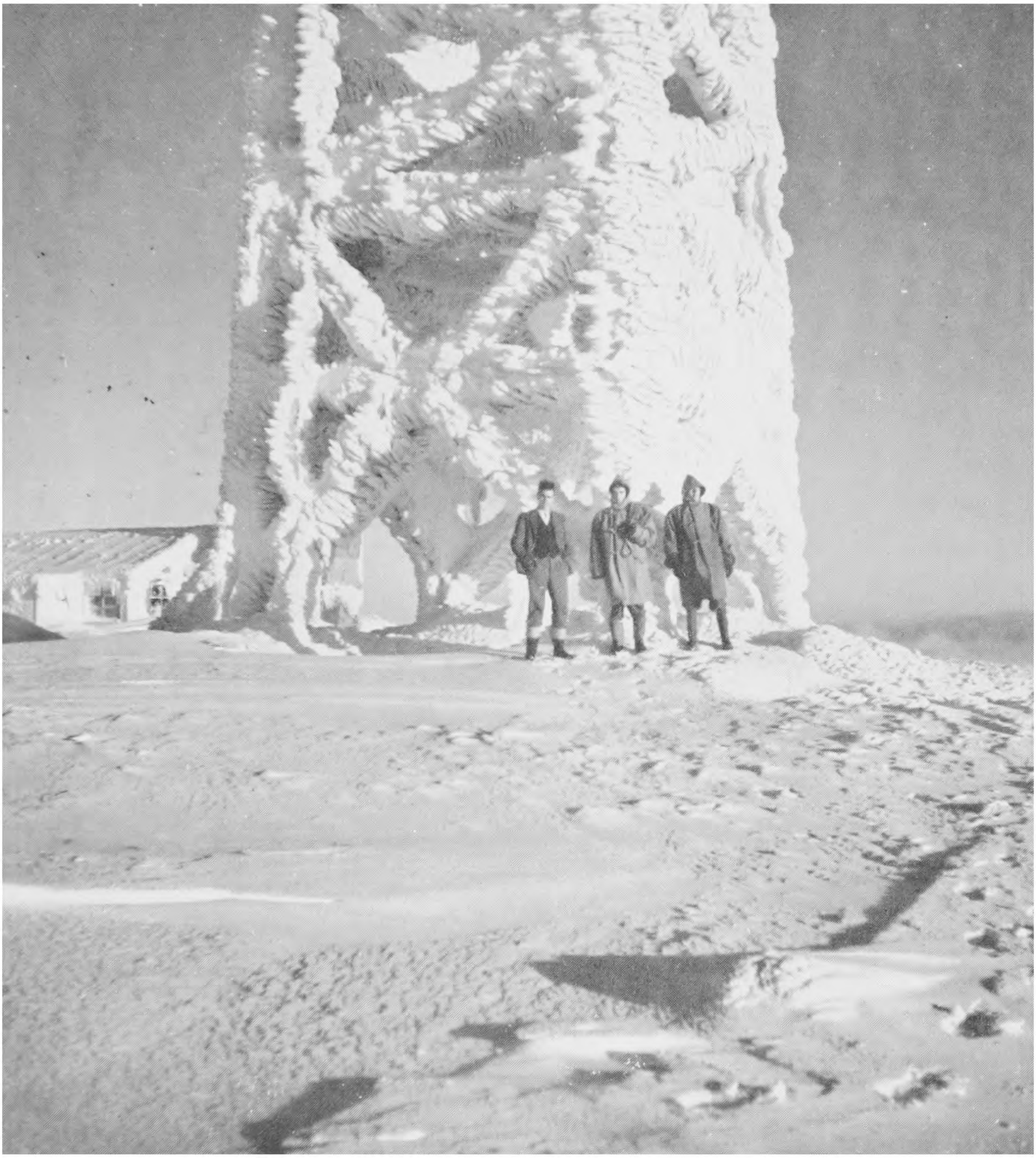
The climatic conditions are similar to those of Iceland. The mountain top is almost permanently in cloud in winter. Wind velocities often exceed 100 m.p.h., and the temperature rises and falls rapidly above and below freezing point, sometimes several times in a day. Under bad conditions ice has been known to build up on masts and other structures at the rate of 1 in. in 20 minutes. Thaws are equally violent.

The staff of the station change watch every two days in winter. Deep snow blocked the road to a point below the 1,200-ft. level for much of the period from November to April last winter. At times the men were forced to climb through to the top on foot, a distance of four miles. The buildings were sometimes almost completely buried and a cutting had to be maintained down to the door.

The two 90-ft. towers shown in one of the photographs are of standard Air Ministry pattern, specially strengthened for the purpose. The 120-ft. wooden tower is the top half of a 240-ft. tower commonly used on radar stations during the war. The buildings are standard Minisrry of Works type hut with double brick walls, double windows and insulated roofing.

" Across deep waters "

A documentary film " Across Deep Waters ", which has recently been released for public exhibition, shows something of the voluntary meteorological work carried out by the officers of British " selected " ships. The film is a pictorial

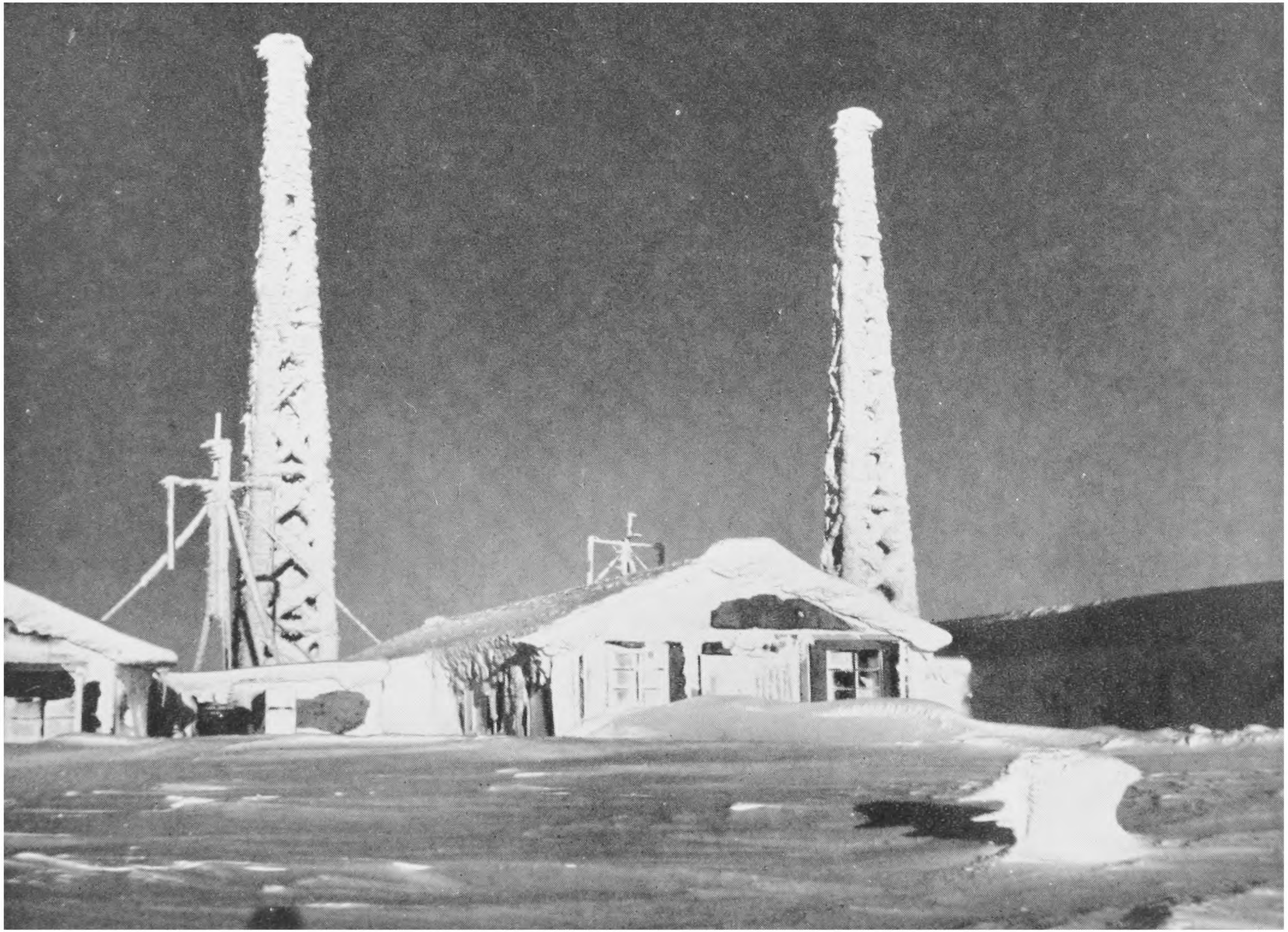


Reproduced by courtesy of D. C. Davies

BASE OF 120-FT. TOWER AT GREAT DUN FELL, CUMBERLAND, JANUARY 16, 1951

All the ice on the 120-ft. tower in the photograph fell off in a few hours, only to build up again later in the day.

To face p. 301]



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GENERAL VIEW OF THE RADIO-TELEPHONE STATION AT GREAT DUN FELL, CUMBERLAND, JANUARY 16, 1951
(see p. 300)
The post in the foreground (4 in. × 4 in. × 6 ft.) marks the road.

record of a voyage from London to Montreal via Belle Isle of one of the "Beaver" cargo ships of the Canadian Pacific Steamship Company. During the course of the voyage an officer is shown making observations of sea-water temperature, barograph and hygrometer, and recording and coding the observations, and then the radio officer is shown transmitting the message. Later, the master and officer on watch are shown discussing a gale warning which has been received, and there are subsequently some very good sequences showing the ship under the influence of the gale.

It is pleasing to see this important voluntary work carried out by ships' officers, which has been done regularly aboard British ships since 1854, thus brought before the public.

C. E. N. FRANKCOM

Boletin Meteorologico

A new quarterly meteorological bulletin, published by the Ministerio de Agricultura e Industrias of Costa Rica, the first number covering the period January–March 1951 by months, has been received in the Meteorological Office Library.

Data are given from 50–51 stations, varying with the element.

The following tables are included:—Rainfall, monthly totals, number of days and maximum in a day; Temperature, monthly means, mean and extreme maxima and minima.

Additional information consisting of a tabulation of all rainfall, daily pressure, relative humidity and cloud observations is given for San José.

REVIEWS

Red Sea and Gulf of Aden. Oceanographic and meteorological data. Koninklijk Nederlands Meteorologisch Instituut. 21 in. × 17 in., pp. 26, *Illus.* Staatsdrukkerij- en Uitgeverijbedrijf, 's-Gravenhage, 1949. Price; *fl.* 10.

This Dutch meteorological and oceanographical atlas covers the sea area from Suez to longitude 52°E. The text is given in Dutch and English. The information is given in roses or figures in 1-degree squares. The number of observations is always provided. The data are all relevant Dutch ships' observations together with a small number of Swedish observations made before 1921. The total number of observations summarized is 482,245.

The contents are:—

(i) Monthly current and wind roses, vector mean winds and currents with constancy in both cases
(ii) Mean monthly surface air pressure and standard deviation
(iii) Air and sea-surface temperature
(iv) Percentage frequency of gales
(v) Percentage duration of "fog" and "dust fog"
(vi) Notes on the occurrence of tropical storms in the Gulf of Aden
(vii) Table of occasions on which a current drift exceeding 73 sea miles in 24 hours was noted.

The charts are beautifully printed and very clear. The use of 1-degree squares, however, produces mean values for many squares off the main shipping route based on very few observations. Thus, the wind rose for April in the square of " origin " 17°N., 40°E. is based on 1,579 observations while one in the square immediately to the west is based on only 54 observations.

There is generally satisfactory agreement between this Atlas and British publications. The percentage frequencies for fog, small as they are, are rather higher than those in the naval handbooks* and raise doubt as to whether they refer strictly to visibility less than 1 Km. There is some disagreement with the " Monthly meteorological charts of the Indian Ocean " in gale frequencies which it is surmised may be due to the Dutch service having calculated them for force 8 or over against the British practice of force 7 or over.

G. A. BULL

The climate near the ground. By Dr. Rudolf Geiger. Translated by Milroy N. Stewart and others. $8\frac{1}{2}$ in. × $5\frac{3}{4}$ in., pp. xxii+482, *Illus.*, Harvard University Press, Cambridge Mass., Geoffrey Cumberlege, London, 1951. Price: $5.00 or 32*s.* 6*d.*

The first edition of the book entitled " Climate of the air layer near the ground ", by Dr. Geiger of the University of Munich, was published in 1927, and has long since been regarded as a classic in that it succeeded in presenting a first-class survey of microclimatological problems and in consolidating into one book the results of widespread research and investigation hitherto available only in disjointed papers and reports.

During the succeeding decade considerable progress was made in this important branch of meteorology not only by meteorologists themselves but also by scientists dealing with allied subjects such as agriculture, medicine and industrial design. A complete revision of the original book was therefore necessary and was completed by the author in 1941. The translation into English was undertaken in America at the end of the war, and shortly before completion it was learnt that a third edition was in course of preparation in Germany. Dr. Geiger consented to supply additions to the second edition so that the present book is the virtual equivalent of the third German edition.

The method of presentation of the subject matter is admirably planned, a factor of great importance when dealing with so complicated a science. The influence that the ground exerts on the climate of the air layer of the first two metres is explained in the first section. In particular the many methods by which heat moves to and from level ground is discussed. The heat exchanges at midday and midnight are examined in general terms, and the roles played by conduction, eddy diffusion and radiation are clearly dealt with. The second section deals with temperature relationships near the ground, explained as consequences of the general principles laid down in the previous section. After discussing the warming process and the cooling process the diurnal and annual course of temperature and temperature gradient are examined and reference therein is made to the researches of N. K. Johnson, A. C. Best and W. D. Flower of the British Meteorological Office, with quotations of the results obtained from the experiments on Salisbury Plain and Ismailia (Egypt). The third section deals with the behaviour of other meteorological elements near the ground—humidity, wind, visibility, dust and optical phenomena. Finally, the fourth section of the first part considers the significance of the type of ground and its influence on the microclimate. The earth's surface can be soil of different texture, colour or degree of moistness, grass, brick, concrete or stone, shallow or deep water, ice or snow, and each type of surface has a different effect on the climate of the nearby air.

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*London, Meteorological Office. Weather in the Mediterranean, Vol. II, Part 12, Red Sea. London, 1936.

London, Meteorological Office. Weather in the Indian Ocean, Vol. II, Part 2, The Gulf of Aden and west Arabian Sea to longitude 60°E. London, 1944.

Part II of the book deals with the influence of topography, vegetation and buildings on meteorological elements in the surface layer of air which may, on occasion, exceed the imposed limit in height of 2m. stipulated in Part I. The first section in this part, section five, considers topography. The pooling of cold air, valley temperatures, up-slope and down-slope winds, the effect of slope on sunshine and consequent microclimate and the general influence of land configuration are treated in the successive chapters. Finally, the range of validity or representativeness of a meteorological station is analysed, and a supplementary chapter deals with the microclimate of caves. Section six considers the influence of plant cover. Plants with their peculiar heat and water economy exercise a considerable effect on the climate and microclimate in which they live, and such effects vary with different crops and different stages of growth. So important is this aspect of the general subject that it is often given other names such as ecoclimate. The influence can grow with increasing size and extent of plant cover so as to affect the general climate or macroclimate of a large region. First, the heat economy of plants, their temperatures and radiation balance are considered, then humidity and wind relationships. Further chapters in this section deal with the meteorology of forests and large stands of trees, considering the radiation, temperature, humidity and rainfall, thence the influence of clearings within a dense forest and the end effects of the forest border. Section seven deals with the relation of living creatures, including man, to the microclimate. Small insects and animals depend for their whole being on the existence of suitable living conditions. Their existence or absence provide excellent indicators and integrators of climatic conditions. Man, on the other hand, either consciously or unconsciously tends to change the climate in which he lives, both by the building of houses and factories and by the creation of cities. As examples of conscious change in climate we have the erection of shelter against the wind and methods of heating to combat frost.

With such a wide range of subjects it is obvious that considerable pruning and compression were necessary to produce a book of less than 500 pages. In fact almost every chapter could with no difficulty at all be expanded into a book or volumes of books of valuable subject matter. It is therefore particularly praiseworthy that at least 50 pages are devoted to an extensive bibliographical list of references, and even then many of the references are specially chosen because they contain further references covering one particular aspect of the subject; in this way, 1,200 other works have been included without specific mention. This admirable feature provides not the least important service of the publication. In comparison, the index of subjects seems too small when one considers the wealth of subject matter. The printing is of a high standard although there are occasional lapses, such as an incorrect heading at the top of p. 193 and the wrong sign in the formula on p. 60. The diagrams are clearly reproduced and well annotated; most of them are self-explanatory and only a few need a careful reading of the accompanying text before their import becomes clear. Some of the theories and supporting arguments are perhaps to be regarded as summaries of the problem rather than final undisputed explanations. The translation is essentially readable, the introduction of occasional colloquial phrases avoiding the stilted impression so often present in scientific translations.

Of the subject itself, it is difficult to overpraise its importance. Climatologists, for the most part, have been driven by force of circumstances and a need for comparable uniformity to deal with an artificial standard " screen " climate. This in itself is the essential first step to obtain knowledge of the microclimate. The present book is an unsurpassed attempt to make further steps towards a complete knowledge of the more real and vital realm of macroclimate. The working synoptic meteorologist engaged mainly in the production of aviation forecasts will find much in the book which will improve his knowledge and appreciation of the vast science of meteorology. To any scientist who is concerned with the important task of applying his skill to the fundamental problems of life and growth the book is invaluable. Both praise and thanks are due to the author for accomplishing the immense work of summarizing the existing knowledge into so small a space, also to the translators who have made available such a wealth of information to the English-reading scientific world.

L. P. SMITH

BOOK RECEIVED

Report on the administration of the Meteorological Department of the Government of India in 1949–50. 6½ in.×9½ in., pp. ii+62, *Illus.*, India Meteorological Department, Delhi, 1951.

OBITUARY

Inspecteur-Général E. Delcambre.—We regret to learn of the death at Denée (Maine-et-Loire) in his 79th year of Général Delcambre. During the first war he was head of the meteorological service of the French Army and, in that capacity, many officers of the British Army Meteorological Section came to know him and to appreciate his vigorous kindly manner. He succeeded M. Angot as Director of the Office National Météorologique de France on November 25, 1920, and held this post until June 30, 1934. During these years he was well known as a member of the International Meteorological Committee and of several Commissions of the International Meteorological Organization. On September 14, 1923, he succeeded Sir Napier Shaw as President of the International Commission for the Study of Clouds and was still President when that Commission was dissolved in 1946. It was this commission that published in 1932 the now familiar " International Cloud Atlas " which replaced the older atlas of 1896; Général Delcambre wrote the Preface to this new Atlas.

Of wide meteorological interests he was President of the Société Météorologique de France and held the office of Secretary-General of the Society from January 1926 until his retirement in 1934. During all this period he and the Office National Météorologique helped the Society considerably, particularly in the early days when it was still suffering from the after effects of the first war.

Whilst he was Director, Général Delcambre wrote two parts of the " Cours de météorologie " which was published by the Office National Météorologique in 1926, Part I, " Instruments et procédés d'observations météorologiques " and Part III, " Sondages aerologiques ". He wrote many articles for *La Météorologie*, the first number of which appeared in 1925 when he was President of the Société National Météorologique, including some on the co-operation necessary between meteorologists and agriculturalists. In 1931 he wrote " L'organisation de la protection météorologique sur l'Atlantique ", in which he suggested the establishment of " stations flottantes internationales " (or ocean weather stations to use the modern term); the cost of each he calculated at $24,000 a year and he suggested the use of sailing ships with auxiliary motors. In 1934 the lecture " Les dictons populaires et la prevision du temps ", which he had given the previous year at Brive, was published in *La Météorologie.* This was illustrated with woodcuts and reproductions of pages from old books.

METEOROLOGICAL OFFICE NEWS

Hurricane in Jamaica.—The Meteorological Office in Jamaica was wrecked and all communications dislocated when the centre of a hurricane passed just south of Palisadoes Airfield at 2215 E.S.T. on August 17, 1951.

The wind exceeded 100 kt., the lowest pressure was 973 mb. (recorded by barograph) and more than 430 mm. of rain fell.

News has been received that all members of the Meteorological Office Staff are safe.

Move of the Training School to Stanmore.—During its relatively short history the Meteorological Office Training School has had its full share of moves. Croydon, Gloucester, and various districts of London have at different times housed the new entrants to the Office. After four-and-a-half years in Kingsway, in the centre of London, the School has moved once more, this time to Stanmore on the north-west outskirts of London.

At Stanmore, the School is accommodated in a plain single-storeyed building in pleasant surroundings. From a technical point of view Stanmore enjoys many advantages over central London, not least of these being a clearer atmosphere. In visibility points, however, Kingsway enjoys an overwhelming advantage. Visibility objects, viewed from the roof of Princes House, ranged to a distance of 18 miles and included such notable landmarks as St. Paul's Cathedral, Nelson's Column, and the Houses of Parliament, guides to English history as well as to the measurement of atmospheric obscurity.

Ocean weather ships.—A special air/sea rescue exercise was carried out in the Firth of Clyde by the ocean weather ships *Weather Explorer* and *Weather Watcher* on July 18, assisted by an aircraft of R.A.F. Coastal Command.

The aircraft approached the ship and was brought down from 3,000 to 100 ft. by radar control. The ship laid a smoke path, dummies representing survivors were dropped by the aircraft for each ship in turn and the dummies were satisfactorily recovered by the ships' lifeboats and other means. A new immersion suit for assisting the " survivors " out of the water was used for the first time with great success. Representatives of the Ministry of Civil Aviation, B.O.A.C. and R.A.F. Rescue attended.

Exhibitions.—The Marine Branch exhibit " The Gale Warning Story ", which consists of 18 original oil paintings by Mr. C. A. Jupp with appropriate explanatory captions, was shown to the Meteorological Association at Harrow on June 30, to the " Shipping and Industries Exhibition " at Southampton, July 7–14, and to the "Daylight on Industry Exhibition" at Liverpool, July 23 to August 14.

Notices in the Southampton and Liverpool press show that the exhibit created considerable public interest on account of its original treatment in tracing the evolution of gale-warning methods from 3000 B.C. to the world-wide system of the present day.

Examination successes.—We offer congratulations to the following on their recent successes:— Mr. J. C. Ascough and Mr. T. Kelly, who have obtained the degree of B.Sc. General (London) in physics and mathematics; Messrs. J. M. Beckley, J. G. D. Beimers, J. A. Clements, L. Dent, G. Douglas, R. A. Ebdon, N. Ellis, A. Gray, G. N. Groves, P. Horsley, A. R. May, who have passed the Intermediate B.Sc. examination of London University.

Horticultural Show.—The Office staff were amongst the prizewinners at the Summer Show of the Air Ministry and Ministry of Civil Aviation Horticultural Society held at Adastral House on July 17: Mr. B. G. Brame (fruit, vegetables and flowers); Miss H. G. Chivers (flowers); Mr. N. E. Davis (vegetables); Mr. H. A. Scotney (vegetables and flowers) and Miss D. J. Wordsworth (flowers). Between them they carried off 25 prizes, including 7 firsts.

Sport.—Mr. S. W. Lewis gained second place in the Civil Service Mile Swimming Championship held at Tooting Bec on July 12, 1951: an excellent performance for so young a member of the staff.

WEATHER OF AUGUST 1951

Mean pressure was above 1015 mb. over a large area extending from north-west Canada south-eastwards to Florida and across the Atlantic covering most of south-west Europe and also parts of central Europe. In an area extending westward of and including the Azores, mean pressure was above 1025 mb. Between northern Scotland and southern Iceland mean pressure was below 1005 mb.

The mean pressure was slightly below normal over the United States and above normal over Canada especially east of the Rockies in Alberta. The British Isles had a deficit of about 5 mb., this area extending to southern Iceland. Over the rest of Europe pressure was also below normal excepting in Scandinavia where it was slightly above and in Finland where it was more than 5 mb. above. The Azores high was further north than usual and this gave an area with pressure above normal in mid Atlantic.

Mean temperature was generally above normal in eastern and northern Europe (including Scandinavia) and in the southern United States. Finland experienced an excess of more than 5°F. while the north coast of the Gulf of Mexico was about 5°F. above normal. Temperatures were generally below normal in south-western Europe (except parts of Spain) and in north-western Canada which had a deficit of 5°F. in places. Mean temperature was just below 100°F. inland over the Sahara and in southern Iraq.

In the British Isles the weather was unsettled and wet, excessively wet in parts of the eastern and central districts of Great Britain. It was rather dull and mainly cool, a feature of the month being the absence of any very warm spells.

In the opening days depressions moved north-east along our north-west seaboard while associated troughs crossed the British Isles. Scattered showers occurred in Scotland and Ireland on the 1st and rain, heavy locally, fell in the west and north on the 2nd, but fair, warm, sunny weather persisted over much of England. The rain spread to most parts of England on the 3rd but did not reach eastern districts until nightfall. Temperature rose to 80°F. locally in eastern districts of England on the 2nd and 3rd and touched 82°F. at Southend on the 2nd and at Hull on the 3rd. From the 5th to the 7th a depression off the south-west of Ireland moved slowly south-east to Brittany and then turned north and filled, while another centre developed over France and moved north over the eastern districts of Great Britain reaching the extreme north-east of Scotland by the morning of the 8th. Heavy rain occurred in the south-west on the 5th and widespread heavy rain, with local thunderstorms on the 6th–7th (2·62 in. at Ashburton, Devon, on the 5th and 2·48 in. at Birdsall Gardens and Burton Pidsea, both in the East Riding of Yorkshire, and 2·42 in. at Connington Castle Gardens, Huntingdonshire, on the 6th). On the 8th another depression off the mouth of the English Channel moved east over France and later turned north to the Low Countries. Rather scattered rain was recorded on the 8th and local rain and thunderstorms occurred in England on the 9th. On the 11th and 12th a depression off south-west Ireland moved east-north-east to the North Sea and was associated with considerable rain in England on the 11th (2·33 in. at Compton, Sussex) and showery weather generally on the 12th and 13th. Subsequently a pronounced wedge of high pressure crossed the British Isles and maintained mainly fair weather on the 14th and 15th. Thereafter unsettled conditions were resumed with low pressure south of Iceland and troughs crossing the British Isles. Rain fell in most parts and was considerable locally on the 16th, 18th and 21st. On the 23rd and 24th a small secondary off south-west Ireland moved north-east to the North Sea and was associated with moderately heavy rain in places on the 23rd and slight rain or showers on the 24th. On the 25th a deep depression south of Iceland moved south-east to a position off north-west Ireland and gradually became less deep. Meanwhile troughs or secondary depressions associated with it moved over the British Isles and maintained unsettled weather, with heavy rain at times, until the end of the month (2·36 in. at Ystalyfera, Glamorgan, on the 25th, 2·41 in. at Ilfracombe on the 26th, 2·06 in. at Oakley Quarries, Merioneth, on the 28th and 2·43 in. at Cowes Water Works, Isle of Wight, on the 30th). Thunderstorms occurred locally on some days, for example, on the 26th–27th, 30th and 31st; they were rather widespread on the 31st.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	82	35	−1·0	156	+3	91
Scotland	75	30	−0·7	125	+2	89
Northern Ireland ...	71	44	−0·7	111	+5	97

RAINFALL OF AUGUST 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	3·66	166	*Glam.*	Cardiff, Penylan ...	4·59	109
Kent	Folkestone, Cherry Gdn.	5·46	229	*Pemb.*	Tenby	5·90	155
„	Edenbridge, Falconhurst	5·44	208	*Card.*	Aberystwyth	...	...
Sussex	Compton, Compton Ho.	7·94	257	*Radnor*	Tyrmynydd	5·63	104
„	Worthing, Beach Ho. Pk.	4·14	183	*Mont.*	Lake Vyrnwy	7·23	136
Hants.	Ventnor...	4·08	200	*Mer.*	Blaenau Festiniog ...	11·00	98
„	Bournemouth	4·14	164	*Carn.*	Llandudno	3·40	121
„	Sherborne St. John ...	4·61	190	*Angl.*	Llanerchymedd ...	4·83	133
Herts.	Royston, Therfield Rec.	4·25	165	*I. Man*	Douglas, Borough Cem.	5·05	133
Bucks.	Slough, Upton... ...	3·10	143	*Wigtown*	Port William, Monreith	4·35	113
Oxford	Oxford, Radcliffe ...	3·67	161	*Dumf.*	Dumfries, Crichton R.I.	5·66	140
N'hants.	Wellingboro' Swanspool	3·99	168	„	Eskdalemuir Obsy. ...	7·15	139
Essex	Shoeburyness	2·27	128	*Roxb.*	Kelso, Floors	2·61	88
„	Dovercourt	3·61	202	*Peebles*	Stobo Castle	4·69	132
Suffolk	Lowestoft Sec. School...	2·28	104	*Berwick*	Marchmont House ...	3·70	112
„	Bury St. Ed., Westley H.	3·41	131	*E. Loth.*	North Berwick Res. ...	3·87	122
Norfolk	Sandringham Ho. Gdns.	3·59	133	*Midl'n.*	Edinburgh, Blackf'd. H.	5·27	164
Wilts.	Aldbourne	4·30	162	*Lanark*	Hamilton W. W., T'nhill	5·03	147
Dorset	Creech Grange... ...	6·03	211	*Ayr*	Colmonell, Knockdolian	5·55	139
„	Beaminster, East St. ...	5·81	186	„	Glen Afton, Ayr San. ...	8·42	156
Devon	Teignmouth, Den Gdns.	3·61	160	*Bute*	Rothesay, Ardencraig ...	4·69	96
„	Cullompton	5·00	164	*Argyll*	Morvern (Drimnin) ...	6·01	114
„	Ilfracombe	8·34	232	„	Poltalloch	4·21	86
„	Okehampton Uplands	5·81	137	„	Inveraray Castle ...	6·75	103
Cornwall	Bude, School House ...	4·48	159	„	Islay, Eallabus... ...	3·91	90
„	Penzance, Morrab Gdns.	4·88	154	„	Tiree	4·11	98
„	St. Austell	5·09	141	*Kinross*	Loch Leven Sluice ...	3·96	103
„	Scilly, Tresco Abbey ...	4·96	180	*Fife*	Leuchars Airfield ...	2·94	95
Glos.	Cirencester	5·31	177	*Perth*	Loch Dhu	8·94	132
Salop.	Church Stretton ...	3·80	114	„	Crieff, Strathearn Hyd.	5·60	133
„	Shrewsbury (Monksmore)	3·24	117	„	Pitlochry, Fincastle ...	6·24	176
Worcs.	Malvern, Free Library	3·78	131	*Angus*	Montrose, Sunnyside ...	3·81	137
Warwick	Birmingham, Edgbaston	4·24	156	*Aberd.*	Braemar	4·33	127
Leics.	Thornton Reservoir ...	5·07	181	„	Dyce, Craibstone ...	3·96	131
Lincs.	Boston, Skirbeck ...	3·51	147	„	Fyvie Castle	3·93	124
„	Skegness, Marine Gdns.	4·06	166	*Moray*	Gordon Castle	3·50	110
Notts.	Mansfield, Carr Bank...	4·82	173	*Nairn*	Nairn, Achareidh ...	4·07	167
Derby	Buxton, Terrace Slopes	5·32	121	*Inverness*	Loch Ness, Garthbeg ...	6·83	210
Ches.	Bidston Observatory ...	5·04	164	„	Glenquoich	10·36	126
Lancs.	Manchester, Whit. Park	4·42	128	„	Fort William, Teviot ...	7·52	121
„	Stonyhurst College ...	5·27	104	„	Skye, Duntuilm ...	3·56	80
„	Squires Gate	4·06	119	*R. & C.*	Tain, Tarlogie House ...	4·57	169
Yorks.	Wakefield, Clarence Pk.	4·27	164	„	Inverbroom, Glackour...	5·21	125
„	Hull, Pearson Park ...	5·31	182	„	Applecross Gardens ...	6·40	136
„	Felixkirk, Mt. St. John...	5·56	195	„	Achnashellach	7·02	111
„	York Museum	5·74	228	„	Stornoway Airfield ...	3·07	81
„	Scarborough	6·23	224	*Suth.*	Loch More, Achfary ...	5·60	96
„	Middlesbrough... ...	5·73	209	*Caith.*	Wick Airfield	2·97	108
„	Baldersdale, Hury Res.	3·22	92	*Shetland*	Lerwick Observatory ...	5·33	177
Norl'd.	Newcastle, Leazes Pk....	4·87	173	*Ferm.*	Crom Castle	4·89	118
„	Bellingham, High Green	3·49	99	*Armagh*	Armagh Observatory ...	4·47	123
„	Lilburn Tower Gdns. ...	3·52	125	*Down*	Seaforde	4·15	111
Cumb.	Geltsdale	3·47	84	*Antrim*	Aldergrove Airfield ...	3·56	99
„	Keswick, High Hill ...	5·44	104	„	Ballymena, Harryville...	4·94	116
„	Ravenglass, The Grove	6·16	135	*L'derry*	Garvagh, Moneydig ...	4·83	123
Mon.	Abergavenny, Larchfield	3·82	128	„	Londonderry, Creggan	3·53	76
Glam.	Ystalyfera, Wern House	11·94	193	*Tyrone*	Omagh, Edenfel ...	5·13	120

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EVIDENCE FOR A STRATOSPHERIC CIRCULATION IN VERTICAL MERIDIONAL PLANES BETWEEN POLAR AND EQUATORIAL REGIONS IN WINTER

By L. S. CLARKSON, M.Sc.

Introduction.—A series of cross-sections through the atmosphere has been published in recent years depicting the distribution with latitude and height along selected meridians of the seasonal means of radio-sonde observations of virtual temperature[1-5]. The mean tropopause shown on most of these cross-sections has been defined, for consistency with the spatial distribution of temperature, as lying at that height at which the mean temperature reaches a minimum in the vertical.

In this paper it is shown that a detailed examination, of the parts of the cross-sections which show seasonal mean temperatures and tropopause heights over equatorial regions, reveals phenomena which are most readily interpreted as being the result of a relatively greater subsidence occurring in the lower equatorial stratosphere in July–August than in January–February.

All available upper air observations from the southern-hemisphere polar regions have been considered, and, after a discussion of insolation errors, various explanations previously proposed to account for the relatively cold antarctic stratosphere observed in winter are examined. It is concluded that none of these is entirely acceptable separately, and that the phenomenon is at least partly to be attributed to relatively greater slow mass ascent occurring in the antarctic stratosphere in July–August than in the arctic stratosphere in January–February.

Further evidence for this conclusion is found from consideration of the published observations of the seasonal variation in the height of the polar tropopause and from a comparison of mean stratospheric temperatures over the poles and the equator.

Finally, the relative subsidence in the lower equatorial stratosphere and the relative ascent in the antarctic stratosphere, deduced earlier as simultaneously occurring in the southern-hemisphere winter season, are considered related in so far as they represent localized features of a general meridional circulation in the stratosphere between polar and equatorial regions in winter. Reference is made to additional and independent evidence for a circulation of this nature contained in publications by Brewer[6], Priestley[7] and Goldie[8].

Equatorial stratosphere and tropopause.—Fig. 1 is a reproduction of isotherms and tropopause heights from Hutchings's cross-sections. In latitude 15°S. at 20 Km. the mean temperature of the lower stratosphere is shown as

−60°C. in July–August and −78°C. in January–February. These figures are confirmed by reference to the tabulated means of radio-sonde temperatures at 20 Km. from Espiritu Santo (15°31′S., 167°13′E.) in July and Vila (17°44′S., 168°19′E.) in February[1]. Thus at 20 Km. the equatorial stratosphere is approximately 20°C. warmer in July–August than in January–February. A similar inference may be drawn from the cross-sections along the 80°W. meridian published by Hess[2]. It has been stated that the stratosphere over Batavia is coldest in January[9], and the Upper Air Climatology Branch of the Meterological Office reports that available evidence from Nairobi indicates an equatorial stratosphere slightly cooler in January than in July[10].

There is also a seasonal variation in the mean tropopause height over equatorial regions. In Fig. 2 the left-hand side depicts the seasonal change in the southern hemisphere along the 170°E. meridian as extracted from Hutchings's cross-sections[1], while the right-hand portion has been taken from Hess's northern-hemisphere cross-section[2] along the 80°W. meridian. These two independently obtained sets of results, when brought into juxtaposition, are seen to be in unison with each other in indicating that the tropopause over the equator is 2 Km. lower in July–August than in January–February. Also at both Nairobi and Aden the frequency of very high tropopauses is greater from December to February than from June to August[10].

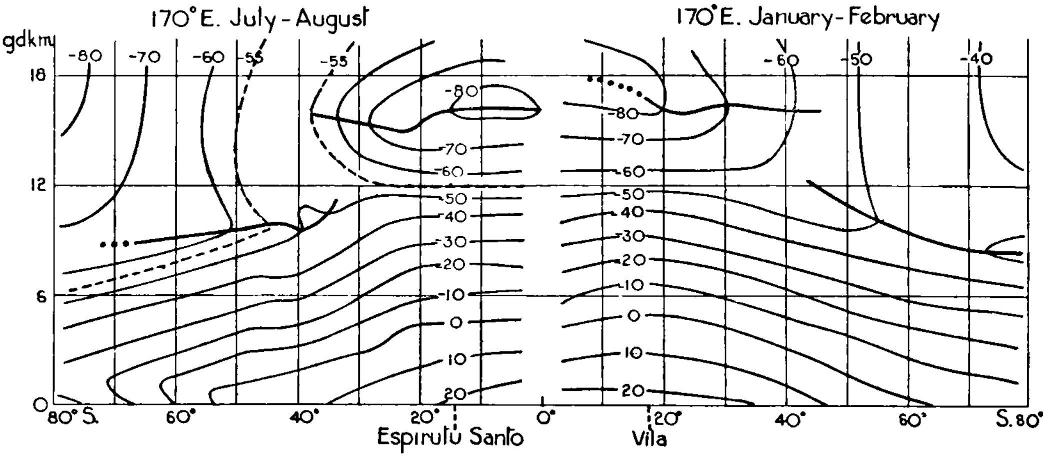

FIG. 1—CROSS-SECTION SHOWING ISOTHERMS (°C.) AND TROPOPAUSE HEIGHTS[1]

Thus the available radio-sonde observations combine to indicate a warmer stratosphere and a lower tropopause over the equator in July–August than in January–February. It is interesting to consider the most probable physical explanation of these facts.

It is generally accepted that at any level in the stratosphere the mean temperature is primarily determined by that equilibrium value at which the emission and absorption of radiation are equal[11]. Except at great heights of the order of 35–40 Km. the atmosphere is but slightly warmed by the direct absorption of short-wave incoming solar radiation. In fact, the lower stratosphere is warmed through the absorption of long-wave outgoing terrestrial radiation by those atmospheric constituents with absorption spectra in the appropriate part of the infra-red spectrum, namely carbon dioxide, water vapour, and ozone. Of these, Dobson[12] has emphasized the importance of ozone, present in low concentration, but possessing an intense absorption band in a region of the infra-red spectrum in which both carbon dioxide and water vapour are transparent.

In the lower equatorial stratosphere at, say, 20 Km. the absorption of long-wave radiation depends on the concentration at this level of water vapour, carbon dioxide, and, more particularly, ozone. Now the water vapour and carbon dioxide concentrations are unlikely to depend on whether the sun is overhead at Cancer or at Capricorn. With regard to ozone, spectroscopic measurements have shown that at the equator the total amount of this gas in a vertical column is seasonally fairly constant. However, such measurements have also shown that in the lower stratosphere the concentration of ozone increases with height[13] and with latitude[12]. Therefore any variation in mean meridional flow or in mean vertical motion from one solstice to the other will alter the mean seasonal ozone concentration at this level. But the mean flow in the lower stratosphere over the equator is almost entirely zonal, so that any seasonal variation in the meridional component must be extremely small. There remains only the possibility of a seasonal variation in mean vertical motion affecting the ozone concentration, and hence the absorptive power of the atmosphere at 20 Km. over the equator.

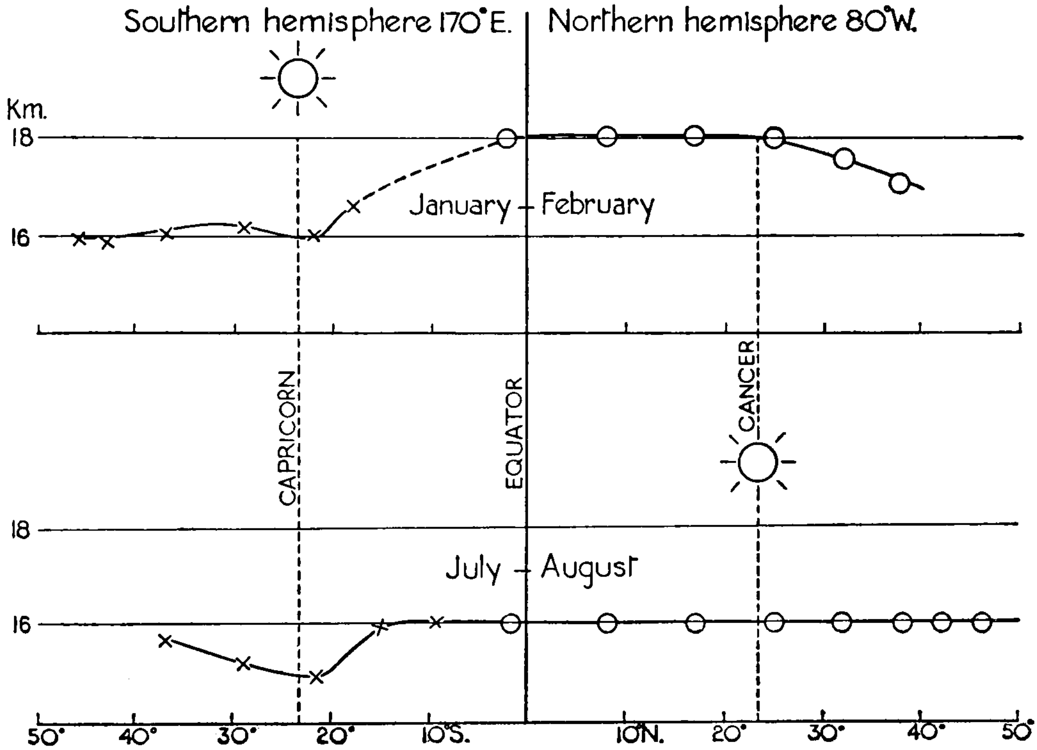

FIG. 2—SEASONAL VARIATION OF TROPICAL TROPOPAUSE HEIGHT

o — mean data from stations near the 80°W. meridian[2]
x — mean data from stations near the 170°E. meridian[1]

The intensity of the stream of long-wave radiation reaching the stratosphere is dependent upon the temperature and water-vapour content of the air in the tropopause, and upon the temperature of the earth's surface beneath. These factors vary very little from one season to the other in equatorial regions[1-3].

The observed rise in mean temperature at 20 Km. from January–February to July–August, if entirely due to radiative effects, must therefore be caused by an increased absorptive power of the atmosphere at this level, which in turn can occur only through an increase in ozone concentration. And it has been shown above that such an ozone-concentration increase can most easily be explained by the downward component of the mean vertical motion being algebraically greater in July–August than in January–February; that is by relatively greater subsidence or lesser ascent in the southern-hemisphere winter season.

The thermodynamic effects of a seasonal variation in vertical motion such as that outlined would also contribute to an increase in the 20-Km. temperature from January–February to July–August, reinforcing the radiative increase, and further, would account qualitatively for the observed seasonal lowering of the equatorial tropopause inversion.

Polar stratosphere and tropopause.—Turning now to the antarctic, over 300 radio-sonde ascents obtained during the Byrd expeditions in summer seasons are available, together with the 18 *Schwabenland* ascents near latitude 68°S. in January and February 1939[5], and the data for summer and winter seasons of 1940–41 from Little America (78°34′S., 163°56′W.) on the Ross Ice Shelf, as quoted by Hutchings, Loewe and Radok, and Flohn.

Insolational errors.—Before considering these results, it is necessary to discuss the probable magnitude of errors introduced into the temperature means through insolation of the recording instruments, since in polar regions in summer the ascents necessarily cannot take place in darkness. In this connexion, Flohn[5] compared a series of ascents from the *Schwabenland* at about 69°S., approximately half of which took place with a solar elevation of 30°, and half with the sun only 4° above the horizon. From the comparison he found that a nomogram due to Väisälä[15], giving the insolational error of Finnish radio-sondes in terms of solar elevation and pressure below 200 mb., is also applicable to the Lange sonde flown from the *Schwabenland*, and that the errors in the uncorrected Little America summer ascents result in an apparent mean summer inversion in the stratosphere of 0·6–0·8°C./Km., whereas the inversion after correction for insolational heating is 0·3–0·4°C./Km. for the *Schwabenland* data, and also for Tromsø, Spitsbergen and Point Barrow in the arctic. It is understood that the Little America data agree with radio-sonde observations obtained more recently by the Anglo-Scandinavian Expedition to Maudheim. They are also consistent with the more extensive means available for lower southern-hemisphere latitudes, and so may be regarded as representative of mean conditions in south polar regions, except that the summer averages incorporate the insolational error to which reference has been made above.

Relatively cold antarctic stratosphere in winter.—In winter the antarctic stratosphere is markedly colder than at corresponding levels in the arctic. Little America, with a mean temperature at 14 Km. in winter of −78°C., is about 15°C. colder than Franz Joseph Land at the same height (Fig. 3), and 20°C. colder than Point Barrow and Arctic Bay[1].

It is interesting to consider those known differences in conditions between north and south polar regions which could contribute to the observed much colder winter stratosphere over the south pole.

Court[16] gives some attention to this point. Referring to the earlier views of Bjerknes and Simpson, he points out that the southern-hemisphere circulation is of a more truly zonal character than that in the northern hemisphere. This

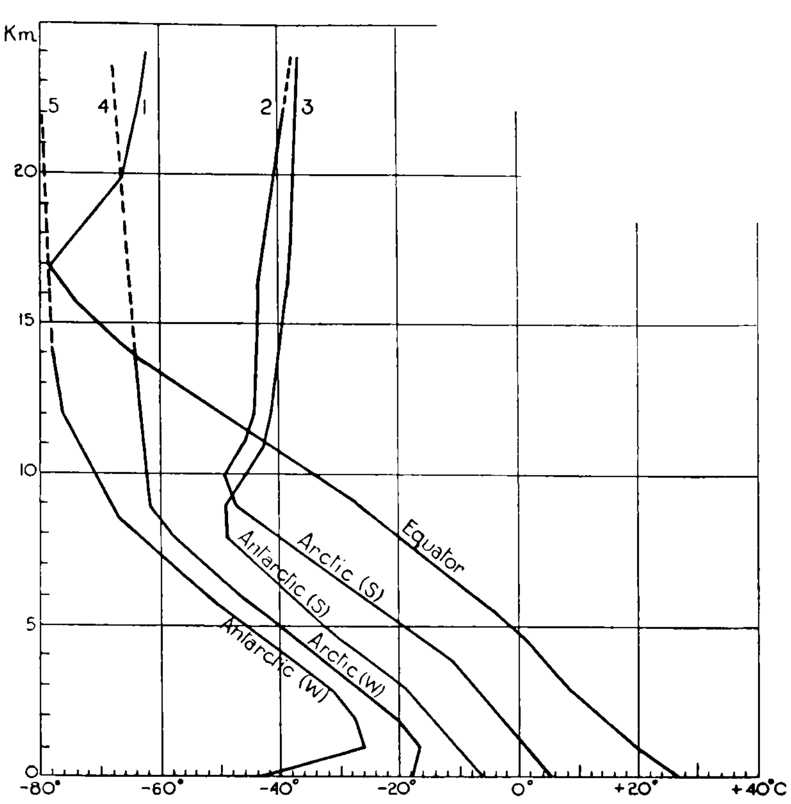

FIG. 3—MEAN TEMPERATURE-HEIGHT CURVES[5]

1 — Equator (annual mean)
2 — Spitsbergen 79°N. (summer)
3 — Little America 78°S. (summer)
4 — Franz Joseph Land 80°N. (winter)
5 — Little America 78°S. (winter)

view is accepted by Flohn[5], and indeed the close correspondence in latitudinal location of significant features shown in the published southern-hemisphere cross-sections along widely differing meridians is strong confirmatory evidence.

This being the case, it follows that the quasi-zonal mean circulation of the southern hemisphere permits of a lesser rate of meridional heat exchange between polar and subtropical latitudes than in the northern hemisphere. Hence it is to be expected that the atmosphere in the antarctic will be colder, and in the mid-latitude zones warmer, than in the northern hemisphere. But available data show that in summer the mean temperature of the southern-hemisphere troposphere up to 500 mb. is 7·5°C. lower in latitude 45° than in the northern hemisphere. This is clearly illustrated in Fig. 4 in which the mean thickness curves for the northern hemisphere, shown by the pecked lines, have been derived by Flohn from circumpolar charts of the 1000–500-mb. relative topography for summer and winter. These charts were plotted in 1943, but have been constantly amended, embracing all the existing aerological material, while the corresponding curves for the southern hemisphere have been drawn by the author from the *Schwabenland* data, together with results obtained by Loewe and Radok and by the fourth Byrd expedition as quoted in Tables 5, 21 and 19 respectively of Flohn's paper[5].

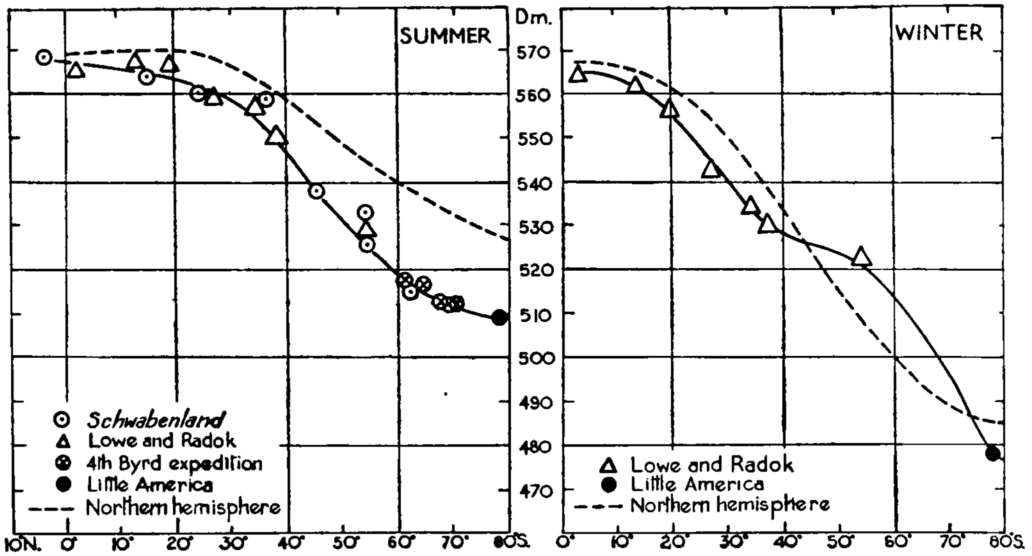

FIG. 4—1000–500-MB. THICKNESS TOPOGRAPHY

A thickness difference of 10 Dm. is equivalent to a mean temperature difference of the 1000–500-mb. layer of 5°C.

The discrepancy between the predictions based on a lesser southern-hemisphere mean meridional rate of heat transfer and actuality is (so far as the colder southern-hemisphere summer troposphere is concerned) usually explained in terms of the greater heat capacity of the more extensive southern-hemisphere oceanic area. But Loewe and Radok[3] point out that this explanation is not acceptable, since the heat stored in the oceans in summer would be returned to the atmosphere in winter, yet in winter, as may be seen from Fig. 4, mean tropospheric temperatures in both hemispheres in middle latitudes are much the same. Instead, Loewe and Radok consider that the colder southern-hemisphere summer troposphere is due to its greater mean cloudiness and consequently greater albedo.

The fact remains that the middle latitudes of the southern-hemisphere troposphere are colder in summer than corresponding zones in the northern hemisphere, and of about the same temperature in winter as the northern-hemisphere counterpart (Fig. 4). Even when current explanations are taken into account, this fact cannot be regarded as supporting the contention that there is a lesser meridional heat exchange in the southern-hemisphere general circulation.

Further, were the much colder winter antarctic stratosphere really due to a relatively isolated south polar circulation, then by the same argument, in summer, lesser lateral mixing with the colder stratospheric air of lower latitudes would, other things being equal, result in an appreciably warmer antarctic than arctic summer stratosphere, whereas in fact, when allowance is made for the Little America summer means being uncorrected for insolational error, Fig. 3 shows that there is very little observed temperature difference.

Court also points out that, in contrast to the arctic, the antarctic continent is a glaciated land mass, so that in north polar regions infra-red radiation from the relatively warm Arctic Ocean passing unabsorbed through the thin ice sheet may be the differential factor required to account for the markedly warmer winter arctic stratosphere. Flohn gives qualified support to this suggestion, which, however, cannot be regarded as completely acceptable until more is known about the infra-red absorption spectrum of ice.

Of course, the fact that the mean winter surface temperature at Little America in the antarctic is −44°C. compared with −18°C. at Franz Joseph Land and −24°C. at Point Barrow in the arctic inevitably means that the energy contained in the heat radiation leaving the antarctic surface is only about 70 per cent. of that originating from the surface in the arctic. But of the long-wave-length radiant energy reaching the respective stratospheres, that part distributed amongst wave-lengths capable of absorption by carbon dioxide and water vapour will be much more nearly equal, since this part of the terrestrial-radiation stream will have been absorbed and re-emitted by the carbon dioxide and water vapour in the respective tropospheres, where the mean temperatures are much less different than at the surface.

The basic question is thus primarily whether the difference in that undiluted fraction of the total radiation, originating at the surface, entering the stratosphere, and distributed amongst wave-lengths capable of absorption by ozone but not by carbon dioxide or water vapour, is sufficient by itself to account entirely for the 15–20°C. lower antarctic than arctic winter stratospheric temperature. In this connexion it is helpful to consider the significance of the very large seasonal range in antarctic stratospheric temperature compared with that at corresponding heights in the arctic. At 14 Km. at Little America the seasonal range is 39°C., whereas at Point Barrow and Arctic Bay the range is only 12–13°C. At the surface in the antarctic the range is again 39°C. and in the arctic 24°C. (Fig. 3). Thus, in the arctic the 14-Km. stratospheric seasonal temperature increase is approximately half that at the surface, whereas in the antarctic it is the same. These facts suggest that the seasonal variations in intensity of that fraction of the terrestrial radiation reaching the stratosphere, if sufficient to account for the arctic seasonal temperature range in the stratosphere, are, *inter alia*, insufficient to explain the proportionally much larger range in the antarctic stratosphere.

At this stage it is suggested that slow mass ascent in the antarctic stratosphere in winter, more pronounced than in the arctic, may be a fourth differential factor. Such a phenomenon would result in a relatively lower winter radiative-equilibrium temperature, since it would reduce the concentration of ozone at a given height in the lower stratosphere[17], and this radiatively produced temperature difference would be augmented by the additional cooling through adiabatic expansion of the air feeding the more pronounced ascent as it converges from higher latitudes into the polar winter high-level cyclone.

Polar tropopause.—Court[16] has discussed the winter ascents made at Little America in detail, emphasizing the observed lifting of the tropopause inversion in autumn, and its eventual complete disappearance towards the end of the winter. The increase in height of the antarctic tropopause from summer to winter is also remarked on by Loewe and Radok[3], and is well illustrated by the seasonal mean temperature-height curves in Fig. 3 taken from Flohn's paper. A similar though smaller effect has been detected in the arctic, at Abisko and at Mount Evans by Möller[18] and Ferguson[19].

These observations strongly suggest that mass ascent is taking place in the polar stratospheres in winter, for the thermodynamically produced temperature changes occasioned by ascent of a stratospheric air column must result in the base of the inversion therein being lifted, and eventually, in the inversion itself being converted into a temperature lapse[20]. This conversion is in accordance with observations, which show that, after correction for insolational error, a temperature inversion definitely characterizes the summer polar stratosphere over Tromsø, Point Barrow, Spitsbergen and the *Schwabenland*, whereas in winter a temperature lapse of 0·5–1·0°C./Km. is found at Franz Joseph Land and Little America (Fig. 3). This winter mass ascent will be relatively more pronounced in the antarctic, for here the tropopause is eventually completely destroyed[16], whereas in the arctic it is normally still detectable even at the end of the winter season.

Furthermore, the abnormally large seasonal range in antarctic stratospheric temperature, which we have maintained is not fully accountable in terms solely of the seasonal flux in outgoing terrestrial radiation, becomes understandable if augmented by a thermodynamical process involving a seasonal variation in mean vertical motion of the nature of that already outlined.

Mean stratospheric temperatures over poles and equator.—In Fig. 3 Flohn has carefully extrapolated the mean winter temperature-height curves for Little America and Franz Joseph Land above 14 Km., adopting for this a lapse rate of 0·5–1·0°C./Km., the same as that actually observed in mean winter observations to 17–20 Km. at Tromsø and Point Barrow. It may be seen that temperatures in the winter antarctic stratosphere are lower than at equivalent levels over the equator. Now Dobson[12] has noted that despite the lesser outgoing terrestrial radiation, the stratosphere is normally warmer in high latitudes than near the equator. This normal tendency is well illustrated by the mean summer cross-section in Fig. 1, and is explained by Dobson as being due to the observed fact that in the higher latitudes mean ozone amounts are much greater than near the equator, so that the thereby increased absorptive power of the high-latitude stratosphere over-compensates for the decreased intensity of the outgoing long-wave radiation stream, and results in the normally observed increase in mean stratospheric temperature from equator to pole. Only in the winter antarctic stratosphere, where temperatures are lower than at corresponding heights over the equator, is an exception found; and, unless the observed mean increase in ozone content with increasing latitude is suddenly reversed in winter in just these regions from whence spectroscopic measurements are either lacking or inaccurate* (namely, polewards of about latitude 70°), it must be assumed that the purely radiative control of mean winter antarctic stratospheric temperature is modified by thermodynamic cooling resulting from slow mass ascent in this region.

Inferred circulation in the stratosphere.—It is significant that the more pronounced polar ascent deduced as occurring in July–August (the antarctic winter) takes place in the same months as the more pronounced subsidence in the equatorial stratosphere. It seems likely that both are part of a general stratospheric circulation in vertical meridional planes between poles and equator, as indicated in diagramatic form in Fig. 5.

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*At the Royal Meteorological Society discussion on the stratosphere, held in February 1951, Dobson stated that recent ozone measurements by means of spectroscopic analysis of starlight and moonlight at Tromsø show low ozone amounts in winter[21], but such observations are in his opinion not yet reliable, because of the low intensity of the light sources necessarily used.

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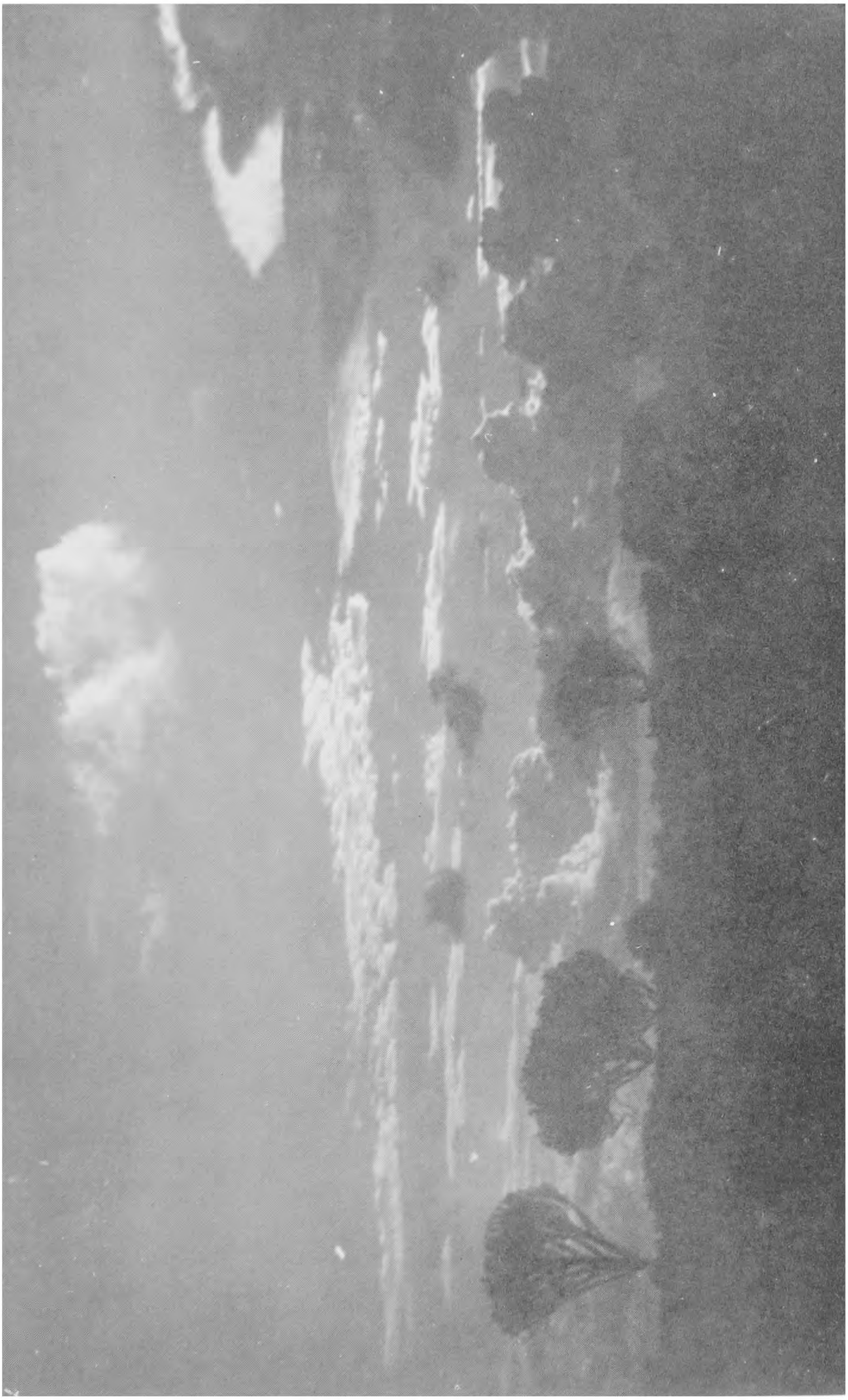

Photograph by the late Mr. M. C. Gillman

HEAVY CUMULUS DISPERSING TOWARDS SUNSET
(see p. 337)

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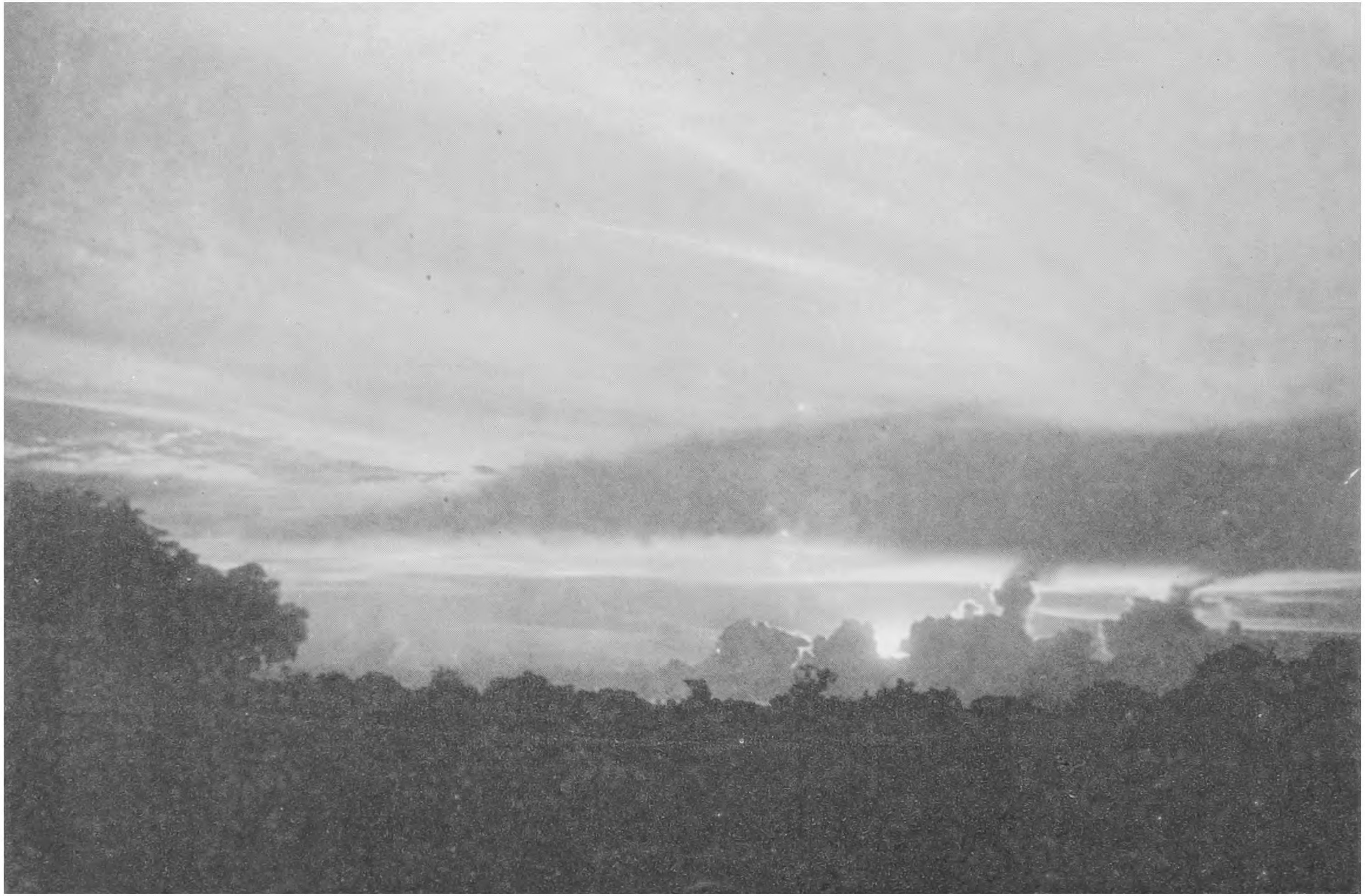

Photograph by the late Mr. M. C. Gillman

HEAVY CUMULUS MERGING INTO A BANK OF CIRROSTRATUS
(see p. 337)

As a result of the thermodynamic and radiational effects of this circulation an otherwise apparently unrelated series of observations now falls into place as the natural consequence of one single mechanism.

Some slight evidence for the high-level quasi-horizontal part of this circulation is provided by Hoffmeister's determination[22] of winds at great heights from observations of meteor trails in the northern hemisphere. Goldie[23] has found that these winds show a mean meridional component from winter pole to equator.

The mean lower-level meridional air flow needed to complete that part of the stratospheric circulation for which evidence has been put forward in this paper has been inferred by Brewer[6], mainly from consideration of the vertical distribution of helium and water vapour in the lower stratosphere. It consists of a mean meridional drift of air from the subtropical upper troposphere polewards in the stratosphere, and then downwards into the temperate and polar troposphere, as indicated by the pecked arrows in Fig. 5. Further, Priestley[7] considers a mean poleward drift of this nature is necessary to preserve the balance in angular momentum across latitudes 30–35°.

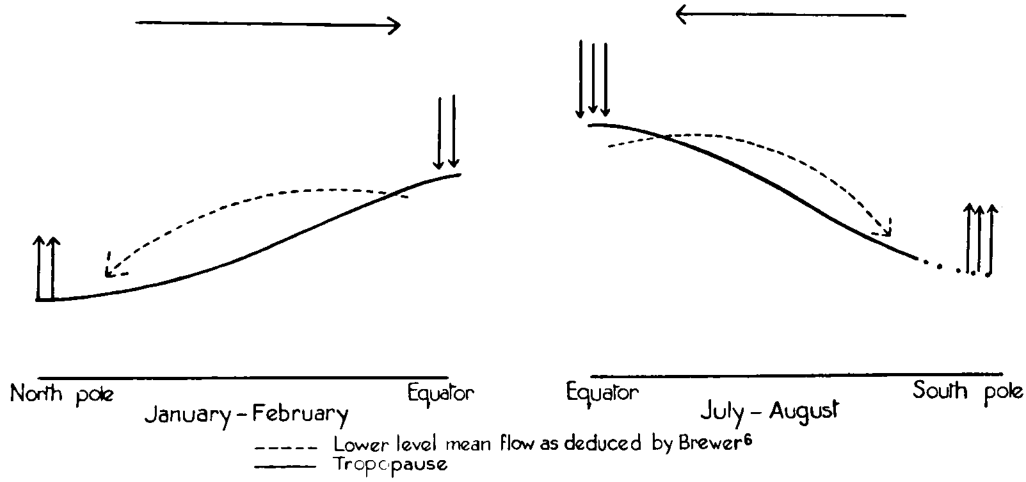

FIG. 5—STRATOSPHERIC CIRCULATION, WINTER SEASON

Goldie[8] has deduced, from density considerations, a world circulation in vertical meridional planes for both winter and summer seasons and covering a range of height from the surface to 45 Km., which is consistent with the requirements of the Bjerknes circulation theorem, and is independently supported by the results of humidity observations in the stratosphere over England. That part of Goldie's circulation relevant to the winter hemisphere between 12 and 28 Km. is similar to the one outlined in Fig. 5, and for which independent evidence has been advanced in this paper.

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METEOROLOGICAL EXAMINATIONS FOR CIVIL PILOTS AND NAVIGATORS

By A. F. CROSSLEY, M.A.

In the interests of safe flying, the licensing of the pilots and other members of the operating crew of aircraft is a means of ensuring that they are fully qualified, in respect of skill, knowledge, experience and medical fitness, to perform their several functions. Minimum standards of qualification have been agreed internationally through the International Civil Aviation Organization, and these standards, together with such additional requirements as are considered necessary in the conditions obtaining in the United Kingdom, have been embodied in the Air Navigation Order 1949, and in the Air Navigation (General) Regulations 1949, which prescribe the licences to be held by the members of the crews of aircraft registered in the United Kingdom.

Types and privileges of licences.—There are separate licences for the pilots of flying machines, gliders, airships and balloons, but in present conditions only the first of these categories is of sufficient meteorological interest to be considered in this note. A flying machine is defined as any power-driven heavier-than-air aircraft, and besides aeroplanes the term includes helicopters, gyroplanes and ornithopters or flapping-wing aircraft (although none of the last exist); each of these kinds of flying machine comprises land, sea and amphibian classes. Originally there were only two pilots' licences for flying machines, the Class " A " and the Class " B ", but with the introduction of the present regulations in April 1949, the Class " A " was replaced by the present Private Pilot's Licence, and the Class " B " by three different categories of

Professional Pilots' Licences, which are obtained after differing requirements have been met, and entitle the holders to correspondingly graduated privileges. Including the learner's or Student Pilot's Licence, there are five pilots' licences in all; these are listed below in ascending order of qualifications required, with an indication of the main privileges conferred by them. In addition there is a licence for navigators.

> *Student Pilot's Licence.*—This is for a person who is still learning to fly, but who has already reached the stage of flying in sole charge of a flying machine. He does his flying only under the orders of a qualified instructor, and is not allowed to carry passengers.
>
> *Private Pilot's Licence.*—This entitles the holder to fly "private" aircraft only, and excludes flying an aircraft for any remunerative purpose. Passengers may be carried.

The next three categories are known collectively as Professional Pilots' Licences, and are primarily for the pilots of flying machines which are being used for purposes of remuneration.

> *Commercial Pilot's Licence.*—This entitles the holder to fly as pilot-in-charge of a public transport aircraft of authorized all-up weight not exceeding 12,500 lb. provided it is not engaged on a "scheduled" journey, i.e. part of a systematic service. The restriction on weight is relaxed when the pilot is flying other than public transport aircraft, or when flying as second pilot on a public transport aircraft, or when flying any aircraft on a non-scheduled journey.
>
> *Senior Commercial Pilot's Licence.*—This entitles the holder to fly as pilot-in-charge of a public transport aircraft of authorized all-up weight up to 15,000 lb. with passengers, or up to 30,000 lb. if passengers are not carried. These restrictions are relaxed when the holder is flying as second pilot, or when he is in charge of other than public transport aircraft.
>
> *Airline Transport Pilot's Licence.*—This entitles the holder to fly as pilot-in-charge of a public transport or other aircraft without restriction as to authorized weight, carriage of passengers or type of journey.
>
> *Flight Navigator's Licence.*—This entitles the holder to fly as navigator on any flight for which the regulations require a qualified navigator to be carried. This requirement applies to flights by public transport aircraft extending 1,000 miles or more over water, or 1,500 miles or more over land. Frequently a Flight Navigator's Licence is held by the first or second pilot.

The licences either include or may be supplemented by various "ratings" defining more closely the activities which may be undertaken by the pilot. Thus all flying licences include an Aircraft Rating specifying the kinds of aircraft which the holder of the licence is entitled to fly in his capacity either as pilot-in-charge or as second pilot. To take another case, a private pilot may obtain a Night Rating empowering him to carry passengers at night, or a Towing Rating if he wishes to tow a glider, and so on. The only rating of any direct meteorological concern is the Instrument Rating which must be obtained before a pilot can fly in conditions which may necessitate instrument flying; it is supplementary to the Private and Commercial Pilots' Licences, involving a separate examination, but with the Senior Commercial and Airline Transport

Pilots' Licences the holding of this rating is compulsory, and it accordingly forms an integral part of these licences.

> *Instrument Rating.*—The holding of this rating qualifies a pilot to fly in Control Areas and Zones under Instrument Flight Rules.

Technical examinations.—The flying licences and instrument rating described above are granted to applicants reaching the requisite standards of flying skill, flying experience, technical knowledge and medical fitness. The authority for granting a licence in this country is the Licensing Section of the Ministry of Civil Aviation. Flying tests are carried out in the main by staff of the M.C.A. Flying Unit at Stansted, Essex, while the technical examinations are conducted at M.C.A. Headquarters by the Training Branches with the assistance of some permanently attached Meteorological Office staff. The subjects for the senior licences include the following: astronomical navigation*, aviation law, form of the earth and aeronautical charts, flight navigation, flight operations†, instruments, meteorology, signals†, and aircraft technical knowledge†. The examinations take the form of written papers and oral tests, and are of a standard commensurate with the privileges conferred by the several licences. Examinations are normally held in London in alternate months for the Senior Commercial Pilots' and higher licences, and in every month for the other licences.

Examinations in meteorology.—Five different levels of examinations are conducted in meteorology. The lowest level is that for the Private Pilot's Licence (there is no technical examination for the Student Pilot's Licence), while at the highest level the standards for the Airline Transport Pilot's Licence and the Flight Navigator's Licence are identical, at least in British practice; further, the standard for the Instrument Rating, when taken as a separate examination, is intermediate between that for the Commercial and that for the Senior Commercial Pilots' Licences.

The examination in meteorology for the Private Pilot's Licence consists of a so-called " objective " or multiple-choice test; for each question, the candidate merely has to state which of three or four suggested answers is the correct one. Once a stock of questions and answers has been compiled, the setting and marking of the papers becomes a routine affair and is conducted by non-meteorological staff.

For the Commercial Pilot's Licence there is a written paper consisting of a number of short questions some of which relate to a synoptic chart, while for the senior licences there are both written and practical papers. The written papers include questions on physical meteorology and its application to aviation, on climatology, and on the meteorological organization and procedures for aviation. The practical examination comprises the plotting of observations from coded data on a partly prepared synoptic chart, the insertion of isobars and fronts (the analysed chart for the period 6 hours earlier being provided), the preparation of an elementary route forecast, and finally the answering of oral questions on the interpretation of the chart. Reference may be made to " Instructions for the preparation of weather maps " during the practical paper, but not when answering the oral questions.

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*Flight Navigators' Licence only. †Not required for Flight Navigators' Licence.

Two specimen theoretical papers are reproduced, one for the Commercial Pilot's Licence and the other for the Airline Transport Pilot's and Flight Navigator's Licences, which are of the same standard in meteorology. Both theoretical and practical papers for the Senior Commercial Pilot's Licence are similar in character to those for the Airline Transport Pilot's Licence although less detailed knowledge is required. Candidates for Instrument Rating take the same theoretical paper as for the Commercial Pilot's Licence, together with a practical paper as for the Senior Commercial Pilot's Licence. An indication of the relative standards in meteorology for the various licences is given by the total time allowed for the respective examinations, namely Commercial Pilot, 1 hr.; Instrument Rating, 2½ hr.; Senior Commercial Pilot, 4 hr.; Airline Transport Pilot and Flight Navigator, 5¼ hr.

To qualify in meteorology, as in most of the other subjects, a mark of 70 per cent. is required, although for the senior licences a mark not below 60 per cent. is accepted in not more than two subjects if the candidate nevertheless attains an average of 70 per cent. or more in the examination as a whole.

Training.—The Ministry of Civil Aviation is not responsible for the training of pilots and navigators, but only for ensuring as far as possible, by means of the examinations and flying tests, that the training in general reaches an adequate standard for the maintenance of safe flying. Training schools are maintained by the air transport corporations and by various other bodies, a list of which may be obtained if required from the Ministry. Close co-operation

(continued on p. 323)

COMMERCIAL PILOT'S LICENCE EXAMINATION

METEOROLOGY

Time allowed—1 hour

SECTION IV. METEOROLOGICAL ORGANIZATION

1. What are the arrangements for the Sub-area broadcasts of meteorological information in the United Kingdom?

2. What do you understand by the term POMAR? Say how and when it is used.

3. What is Regional QFF and what are its uses?

4. Say what action you would take, including information supplied by you, when requesting a flight forecast from a meteorological officer.

5. What cloud details are given in a message in the AERO code?

SECTION V. GENERAL METEOROLOGY

*1. Estimate the wind speed and direction at 2,000 ft. over SCILLY (49·9°N., 06·3°W.).

*2. What is the present weather (Code ww) reported at HONILEY (52·4°N., 01·7°W.)?

*3. What is the visibility in miles at PLYMOUTH (50·4°N., 04·1°W.)?

*4. Give three reasons for placing the cold front between VALLEY (53·3°N., 04·5°W.) and DUBLIN (53·4°N., 06·3°W.).

*5. Having left SILLOTH (54·9°N., 03·4°W.) at 0900 G.M.T. with altimeter set to QNH, what would be your altimeter error in feet on arrival at SHANNON (52·7°N., 08·9°W.) three hours later at the time of the chart? (assume 1 mb. = 30 ft.).

6. Describe, briefly, the diurnal variation in the wind between the surface and 1,500 ft.

7. Explain the formation of glazed ice on aircraft in flight.

8. How is advection fog formed? Give a typical meteorological situation that could give rise to advection fog.

9. What weather would you expect to experience during a passage of a " ridge of high pressure " across the British Isles?

10. Say what you can about the formation of stratocumulus cloud.

***Questions marked with an asterisk refer to a chart which is provided at the examination but is not reproduced here.**

EXAMINATION FOR FLIGHT NAVIGATORS' AND AIRLINE TRANSPORT PILOTS' LICENCES

METEOROLOGY

PART II

Time allowed—3 hours Marks 250

INSTRUCTIONS

1. *Six Questions ONLY are to be attempted. Questions Nos.* 1 *and* 2 *are Compulsory.*
2. *Question No.* 1 *carries* 50 *marks, other questions carry* 40 *marks.*

Question No. 1 (Compulsory Question)

Write an account, from an aviator's point of view, of the climate of one of the following routes, giving special attention to seasonal variation:—

(*a*) ALGIERS (37°N., 3°E.)—KANO (12°N., 8°30′E.)—LAGOS(6°30′N., 30′E.)
(*b*) MARSEILLES (43°N., 5°E.)—MALTA (36°N., 14°30′E.)—CAIRO (30°N., 31°E.).

Question No. 2 (Compulsory Question)

Describe the arrangements in force whereby all meteorological offices in the United Kingdom have available to them full information as to weather reports, frontal structures and any other meteorological data necessary for the efficient functioning of the aviation forecasting service.

Question No. 3

Describe the weather normally associated with polar maritime air as it passes over the British Isles from north-west to south-east (*a*) in summer and (*b*) in winter.

What modifications would be expected if the air arrives over the British Isles from the south-west after being diverted over the Atlantic?

(Information on the geographical distribution of weather and the effects of diurnal variation should be included).

Question No. 4

Discuss the relationship between pressure gradient and wind showing how the gradient wind in a depression differs from that in an anticyclone.

Show also why, for a constant geostrophic wind, the spacing of the isobars differs with latitude and with temperature.

Question No. 5

Describe and account for the diurnal variation of radiation fog

(*a*) in winter
(*b*) in summer.

In the case of airfields located (i) in a valley and (ii) near a large town, explain the probable effects of such situations on the occurrence of fog.

Question No. 6

What do you understand by an " adiabatic change of temperature" ? Under what natural circumstances can air be assumed to change temperature adiabatically?

If the adiabatic relationship between absolute temperature and pressure is:

$$\log T_1 - \log T_0 = 0{\cdot}288\ (\log p_1 - \log p_0)$$

calculate the increase of temperature of a mass of air after descending from 500 mb. to 700 mb. if its initial temperature is -20°C.

Question No. 7

Write notes on two of the following:—

(*a*) Pressure-pattern flying.
(*b*) The effects of ocean currents on weather.
(*c*) Supercooled water.

Question No. 8

What do you understand by " convergence " at a front? ...

Explain the importance of convergence in relation to the rate of advance of

(*a*) warm fronts
(*b*) cold fronts.

Show, also, why no rain would be experienced during the passage of a front if the winds were strictly geostrophic.

is maintained between the Ministry of Civil Aviation and all interested parties in the aviation sphere on such matters as details of syllabi and the arrangements for examinations and flying texts.

The standard meteorological text-books in most frequent use by candidates are the " Meteorological handbook for pilots and navigators " for the lower licences, and Sutcliffe's " Meteorology for aviators " for the Senior Commercial Pilot's and higher licences. Both these books require to be supplemented by the " Air Pilot (United Kingdom)" Part II for information on meteorological organization and procedures; also for the Airline Transport Pilots' and Flight Navigators' Licences, a work such as Kendrew's " Climates of the continents " is required, even though this was not written for the purposes of aviation.

Publications.—Detailed information regarding the issue of licences for flying is contained in a series of pamphlets obtainable from His Majesty's Stationery Office; these are M.C.A.P. 40 " Flight navigator's licence ", M.C.A.P.53 " Student pilot's and private pilot's licences ", M.C.A.P. 54 " Commercial pilot's licence ", M.C.A.P. 55 " Senior commercial and airline transport pilots' licences ", and M.C.A.P. 56 " The instrument rating ". For dates of examinations, amendments to the pamphlets and other matters, reference should be made to the current series of Information Circulars issued by the Ministry of Civil Aviation

ABRUPT SEASONAL CHANGES IN TROPOPAUSE LEVEL AND STRATOSPHERE TEMPERATURE AT HABBANIYA

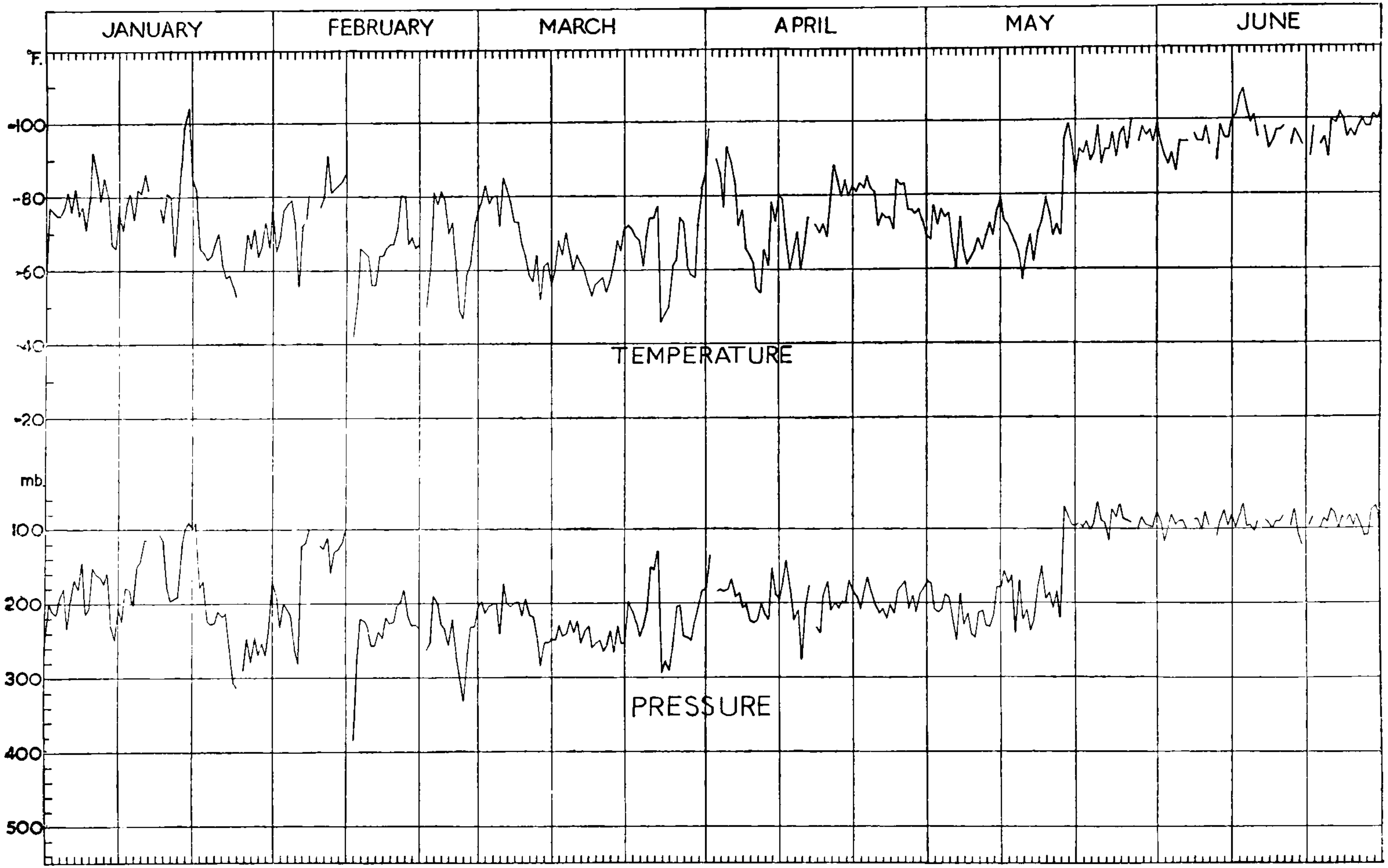
By D. DEWAR, B.Sc.

An examination of radio-sonde ascents made at Habbaniya, Iraq (33°22'N., 43°34'E.) during 1948 showed that an abrupt change occurred in the tropopause pressure and temperature in June with another well marked change in October; during the summer months the tropopause was found to be at a considerably greater height than during the other months. Similar changes are shown by the data for 1949 and 1950, and it appears that during the summer months the upper air over Habbaniya follows a characteristically tropical régime with a high cold tropopause while during the remaining months a temperate régime prevails. The periods for which the tropical régime persisted during the different years were:—

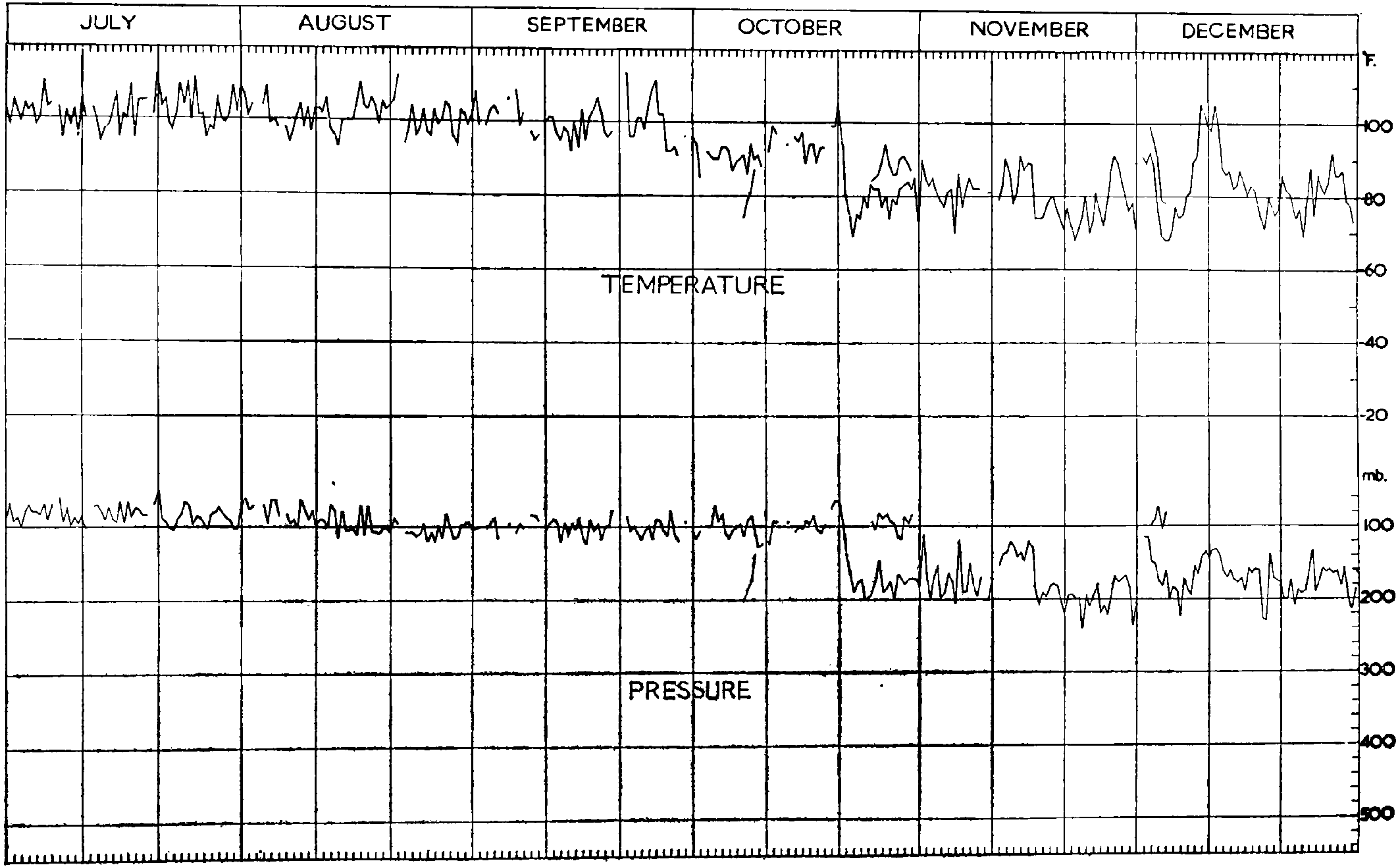
1948 June 9 to October 9
1949 May 11 to October 23
1950 May 19 to October 20

A graph of the daily values for 1950 is given on pp. 324 and 325. Ascents were made twice a day at approximately 0200 and 1400 G.M.T. but the tropopause was not always reached.

It will be noticed that two tropopauses are sometimes shown in October. From this month onwards stations were asked, when two tropopauses could be detected, to give data for both; before that date the ruling had been that for double tropopauses the data reported should refer to the first one reached. The graph suggests that double tropopauses often occur around the transition period, and probably throughout the winter half-year as has been found for stations in similar latitudes in Japan and Australia.



SEASONAL VARIATION OF THE TROPOPAUSE TEMPERATURE AND PRESSURE OVER HABBANIYA (33°22′N., 43°34′E.)
January–June 1950



SEASONAL VARIATION OF THE TROPOPAUSE TEMPERATURE AND PRESSURE OVER HABBANIYA (33°22′N. 43°34′E.)
July–December 1950

The correlation r between pressure and temperature at the tropopause and also the mean pressure $\overline{P}$ and temperature $\overline{T}$ and standard deviations σ_P, σ_T were computed for each régime using data for the three years, and the following values were obtained:—

	r	$\overline{P}$	σ_P	$\overline{T}$	σ_T
		mb.	mb.	°F.	°F.
Temperate régime	0·8	189·4	60·0	−74·2	12·4
Tropical régime	0·3	91·8	15·0	−99·7	6·3

They reveal a very interesting difference between the two régimes of upper air temperature; with temperate tropopauses there is a significant correlation between the pressure and the temperature at the tropopause and a considerable range of pressure and temperature values, while with tropical tropopauses there is a much smaller scatter of the values and no significant relation between temperature and pressure. Calculation of the standard errors confirms that these differences are without doubt significant.

GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS, BRUSSELS, 1951

By H. W. L. ABSALOM, B.Sc., D.I.C.

The International Union of Geodesy and Geophysics, comprising the International Associations of Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Physical Oceanography, Vulcanology and Hydrology, held its ninth general assembly from August 21 to September 1, 1951, in Brussels where the Union, along with other international scientific unions, was instituted in 1919. Some 950 delegates and guests from about 40 countries were present. The assembly, planned long in advance, covered a period two days longer than the assembly in Oslo in 1948. Certainly the period was one of sustained, usually concentrated, activity. Immediately preceding the assembly proper there were meetings in Brussels of the Joint Commission on Radio-Meteorology, of the International Union of Geodesy and Geophysics Commission on Radiation with the World Meteorological Organization Sub-Commission on Actinometry, and of the Joint Committee on the Physics of the Earth's Interior.

In the Free University, pleasantly located about two and a half miles from the centre of the city, provision was made for Union and Association offices and for most of the meetings. Here also, in the Cité Estudiantine, a number of delegates resided and many more availed themselves of restaurant facilities. The Belgian National Committee had arranged for firms from several countries to display geodetical and geophysical instruments in the Great Hall of the University.

The inaugural corporate gathering of the Union took place on the morning of August 21 in the Palais des Beaux-Arts in the city, when, in the presence of Queen Elisabeth of the Belgians, speeches of welcome were made by the President of the Royal Belgian Academy, the President of the Belgian National Committee for Geodesy and Geophysics, the Senior Alderman for Education, representing the Burgomaster of Brussels, and the Minister of Education. At the first plenary session which followed, the President, Dr. F. A. Vening-Meinesz, after reference to Union affairs discoursed on certain features of the conformation of the earth's crust. The General Secretary, Dr. J. M. Stagg, then summarized his report for 1948-50, drawing attention to the eight new member countries, the relations between the Union and other international organizations and the Union's financial indebtedness to U.N.E.S.C.O. to which it is affiliated through the International Council of Scientific Unions. After these collective preliminaries and participation of lunch in the imposing Salle de Marbre at the invitation of the Belgian National Committee, the seven individual Associations commenced their specialized yet wide-reaching activities. Their meetings that afternoon were held in rooms placed at their disposal in the nearby Palais des Académies.

The Associations, on a common basis in relation to the Union though differing among themselves in matters of internal structure and procedure, followed broadly the same type of programme during the assembly. Presentation and discussion of scientific papers occupied the greater part of the meeting time of all. Joint meetings were held by two or more Associations on subjects of common interest. Interspersed among these activities were others such as the hearing of reports from National Committees, the consideration of reports on international projects sponsored by Associations, consideration of representation on, or co-operation with, other international bodies, and the discussion of proposals and recommendations.

Association of Meteorology.—In his Presidential Address to the Association of Meteorology (I.A.M.) Prof. J. Bjerknes, in continuation of a contribution made by him at the Oslo meeting, referred to developments in our understanding of the general atmospheric circulation which have taken place since the presentation of Dr. H. Jeffreys's paper to the Association at Lisbon in 1933. He described recent work under his leadership in California on the transfer of angular momentum at levels up to the stratosphere in relation to the maintenance of the westerlies; work which would not have been possible without the regular upper air observations now available, nor practicable without the assistance of associate workers and computing machinery. The publication of this address will be welcomed by meteorologists.

The programme of the Association of Meteorology was noteworthy for prearranged symposia on main fields of research as follows, with names of chairmen:—cloud physics (Prof. T. Bergeron), radiation (Dr. A. Ångström), micrometeorology (Prof. O. G. Sutton), atmospheric ozone (Prof. G. M. B. Dobson), general circulation of the atmosphere and the oceans—jointly with the Association of Physical Oceanography (Prof. C.-G. Rossby and Prof. H. U. Sverdrup), and physics of the high atmosphere—jointly with the Association of Terrestrial Magnetism and Electricity (Prof. J. Kaplan). By the criterion of the countries of origin of the set contributions alone these symposia were satisfyingly international in character, with the British Commonwealth well represented. The number and length of set contributions at some sessions limited the time for general discusion; the symposia on cloud physics and general circulation each extended beyond the full day originally allotted. Regarded as a whole, these concerted discussions presented a comprehensive picture, with considerable detail, of the work which is in progress on the dynamical and physical processes in the atmosphere from the surface layer to great heights, and of advances achieved and foreshadowed by the application of the latest observational and theoretical techniques. There were joint discussions on evaporation at the surface of the earth and on microseisms with the Associations of Hydrology and Seismology, respectively. Concurrently with other meetings a day was devoted to the consideration of climatological and other topics.

During the meetings the Association of Meteorology learned from its Commission on Radiation of the work proceeding at Davos in the perfecting of instruments—in particular, a radiation-balance meter—and of the work at Uccle on filters. The Commission on Ozone, with headquarters at Oxford, reported that under its auspices the planned network of ozone stations in western Europe, including Iceland and the Azores, is nearly complete; and that ozone spectrophotometers are or will soon be in use in Afghanistan, India, Pakistan, New Zealand, the United States and Canada.

In an address on the subject of an international meteorological institute Prof. Rossby mentioned that an institute for advanced study and research is in process of formation in Stockholm and that it is hoped to secure staff from various countries. M. Viaut announced that a meteorological research centre will be established by the French Government in 1952 and that workers from other countries will be welcome.

An early evening visit to the Royal Belgian Meteorological Institute at Uccle Observatory enabled a numerous company to see the extensive radiation equipment in operation, the array of experimental rain-gauges and many other instruments, and the start of a radio-sonde ascent in which apparatus was carried to record the atmospheric electrical potential gradient. Those present will gratefully remember the hospitality dispensed alfresco by Dr. and Madame Lahaye and their helpers.

Association of Terrestrial Magnetism and Electricity.—A feature of the Association of Terrestrial Magnetism and Electricity is the activity maintained between assemblies by a number of Committees (fourteen at present) charged with the sponsorship of specific projects or general international coordination of various aspects of work with which the Association is concerned. Prof. S. Chapman's address as President ranged widely over the field covered by the Association: the development of the science and of international collaboration therein; the present scope, from the earth's core to the ionosphere, and the contacts with other branches of science; the increasing interest in the physics of the high atmosphere and the possibility of making specific provision for this within the Association; the main features of the work of Committees and suggestions concerning items to be considered during the assembly. The President referred to some recent developments. Observations of the daily variation of horizontal component of magnetic force made in low latitudes in America, Africa and India, at the instance of the Association, indicate the occurrence in the ionosphere (near the magnetic equator) in daylight hours of an intense eastward electric current—an electrojet—of small latitudinal breadth. The trend of the latest work on the earth's magnetism favours the view that the main field has its origin in electric currents in the earth's core, that changing eddies in the core give rise to subsidiary electric-current systems near the surface of the core and are responsible for anomalies in the earth's field and for its secular variation.

Turning from the main field of the earth there is now confirmation, from the auroral spectrum, of the theory long maintained that magnetic storms and auroræ are due to the ejection from the sun of some of its atmospheric gas. Records of the intensity of the earth's magnetic field obtained during recent rocket ascents in America have indicated the situation of the electric currents, due to solar wave radiation, which are responsible for the daily magnetic variation; further exploration by this means is highly desirable. Included among the subjects discussed at ensuing meetings were the development of magnetic airborne surveys in several countries, the physics of geomagnetic secular change, the variation with depth of the earth's magnetic field as shown by measurements in coal mines, the electrical conductivity of the earth's mantle or crust, the progress made in evaluating the lunar variation in the magnetic field and atmospheric pressure, an electrometer for atmospheric electrical measurements in conjunction with radio-sonde measurements and photo-electric registration in application to magnetographs. The valuable work of the Committee on Characterization of Magnetic Disturbance was noted. The three-hourly index (K) of the magnetic effects of solar-particle radiation and the more recently devised three-hourly planetary index find application not only in studies of solar-terrestrial relationships, but in practical matters of radio communication. While the Committee's proposal to replace the daily international magnetic character figure, used since 1906, by a similar but more objective index based on the three-hourly planetary index was not accepted for early introduction, further study on this point was recommended, and also on the possibility of devising measures of the magnetic effects of solar wave radiation and of the intensity of the equatorial ring current.

First-hand evidence of current development in Belgian provision for geophysical work was obtained during the Association's visit to the new geophysical centre situated at 700 ft. in open country near Dourbes, about 55 miles southward of Brussels and remote from sources of electrical interference, atmospheric pollution and night-sky glare. On the extensive site, installations, well spaced to avoid mutual interference and some in underground chambers, are to be made for measuring the magnetic field, earth currents, atmospheric electricity, ionospheric structure, the radio-electric field of distant radio stations, cosmic radiation, solar radiation, "sferics" and seismic movement. The magnetic section is about to operate. Early in the evening return drive to the city the company were entertained to a most welcome meal at Couvin.

Association of Hydrology and Association of Physical Oceanography.—Circumstances prevent the inclusion here of even a superficial general survey of items of meteorological interest in the proceedings of the Association of Hydrology (e.g. in the discussions of snow and ice areas and of surface water) or of the Association of Physical Oceanography. Reference is therefore limited to questions of modification of climate and of general circulation raised by the recession of the Ruwenzori glaciers at the 4,000–5,000-m. level in equatorial Africa; and to the studies in progress on deep ocean sediments as provided in the long cores obtained by the Swedish "Albatross" expedition —work which indicates the possibility of determining the major climatic changes of the last million years.

Association of Seismology.—The Presidential Address by Dr. R. Stoneley to the Association of Seismology was devoted to the International Seismological Summary which has been and is largely a British contribution in this field of international co-operation.

Final plenary session.—The strands were gathered together at the final plenary session of the Union in the Palais des Beaux-Arts on the last day. Main features of the activities of the Association were reported by the respective Presidents. Resolutions proposed by the Council of the Union and by Associations were adopted. The Union approved in principle, and made recommendations concerning, a proposal from the Joint Commission on the Ionosphere that arrangements should be put in hand for a third " international polar year " project in 1957–58. It approved and made suggestions regarding the scheme for " world days " in upper atmospheric research as proposed by the Joint Commission on High Altitude Research Stations. It recommended for trial the use of certain of the terms, but recorded reservation on other terms, contained in a memorandum on " Upper atmospheric nomenclature ", prepared by Prof. S. Chapman, which had been referred to the Union by the Joint Commission on the Ionosphere. It was agreed that further consultation should take place within the Union and with other interested bodies as to the best method of making adequate provision within an international organization for the subject of the physics of the high atmosphere; and that endeavour should be made to obtain funds from international sources to enable the non-magnetic ship *Research*, which was constructed by the British Admiralty before 1939, to be fitted out and brought into service so that much needed ocean magnetic survey may be undertaken. Another resolution stated that the Union would welcome resumption of U.S.S.R. contributions to the international scheme of magnetic indices, and invited the general co-operation of the U.S.S.R. in the work of the Union. Announcement was made that Prof. S. Chapman succeeds Prof. F. A. Vening-Meinesz as President, and that Dr. J. M. Stagg, after six years as General Secretary, has resigned and is succeeded by Colonel G. Laclavère. Other newly elected Presidents include—Dr. K. R. Ramanathan, Meteorology; Prof. J. Coulomb, Terrestrial Magnetism; Prof. J. Proudman, Oceanography. By invitation the next assembly, in 1954, will be held in Italy.

So ended the ninth general assembly of the International Union of Geodesy and Geophysics which, on current impressions and in retrospect, was highly successful, and not merely on grounds of size. Gatherings of this scope stimulate individual and international activity, provide a forum for public exposition and discussion, and also afford opportunities for the making and renewal of more intimate personal contacts—with exchange of views and information—between individuals. All this is true of the Brussels assembly. But this is not all. Those who were privileged to attend the assembly are deeply grateful for the warmth of welcome, the interest and the generous hospitality of the host country, made evident in so many ways. Queen Elisabeth graciously received the members of the Council and Executive Committee of the Union and their wives at the Palace of Laeken. On the opening day a reception was held in the Hôtel de Ville by the civic authority of Brussels, and on the last day but one the general company were entertained to dinner in the Palais des Beaux-Arts by the Belgian National Committee. A large body of delegates and guests were taken to Antwerp, conducted over places of interest according to choice, entertained to lunch and taken by steamship for an afternoon tour of the port. Other excursions were arranged to other cities and parts of Belgium according to the general and scientific inclination of delegates. In addition a special Committee watched over the interests of ladies and arranged a variety of visits. Finally, tribute is due to the Belgian National Committee and others for the admirable arrangements made to ensure the smooth working of the assembly.

BOOKS RECEIVED

Annual reports for 1937, 1938, 1939. Christchurch Magnetic Observatory. 6 in.×9½ in., pp. xiii+144, New Zealand Department of Scientific and Industrial Research, Wellington, *s.a.*

TURBULENCE AT HIGH ALTITUDE : A FURTHER METEOROLOGICAL ANALYSIS

By J. K. BANNON, B.A.

Introduction.—It has been shown[1] that the occurrence of turbulence in the upper troposphere and lower stratosphere of such a nature as to cause noticeable abnormal movement of an aircraft (bumps) is in many cases associated with small values of the meteorological parameter, the Richardson number. It also seems to be associated with abnormally large shear of wind in the horizontal, but neither of these two parameters appears to be necessarily associated with the occurrence of bumps.

In previous meteorological analyses of high-altitude turbulence[1,2,3] suitable observations of wind and temperature were seldom available at the same time and place as the occurrence of the bumps, so that interpolation in space and time was necessary to obtain appropriate values of the meteorological parameters. However, marked changes can occur in the upper air within a short distance and in a short time, and there is always the suspicion that interpolation in the meteorological variables may have invalidated some of the conclusions.

This note is a summary of an analysis[4] of a number of occasions of turbulence experienced between heights of 18,000 and 40,000 ft. on ascents by the Meteorological Research Flight during 1950 made primarily to observe humidity and temperature at high altitude. It was possible to make the flights within 10 miles of one or other of the upper air observing stations at Larkhill and Downham Market, and also within 20 min. of the time the observations of upper winds were made at those stations. Thus appropriate values of the meteorological variables were available for the analysis.

Cases of general shear in the vertical.—It has generally been assumed that the most important factor causing turbulence at high altitude is large wind shear in the vertical. For analysis the cases were therefore placed in one of two categories according as a general shear in the vertical was present or not.

Table I gives mean and median values of Richardson number and isentropic shear for the bumpy layers occurring in a general change of wind with height.

TABLE I—TURBULENCE IN A GENERAL SHEARING LAYER: RICHARDSON NUMBERS R_i AND ISENTROPIC SHEARS

	No. of layers	Depth	R_i below	R_i in turbulent layer	R_i above	Isentropic shear
		ft.				hr.$^{-1}$
Troposphere						
Mean	57	2,000	6·2	2·4	11·7	0·21
Median			3·3	1·6	4·6	0·18*
Stratosphere						
Mean	17	2,000	10·1	3·5	16·4	0·21
Median			3·8	2·2	9·1	0·17†

* 29 cases † 11 cases

The turbulence, assessed qualitatively, was classed as moderate in 11 cases and as slight in the remaining cases. It is seen that, notwithstanding certain errors which tend to increase its calculated value, the Richardson number, R_i, is usually small (order 1 to 3) in the turbulent layers, and that R_i is usually considerably greater above and below the turbulent layers. Horizontal shear is nearly always greater than isentropic shear, and thus it is seen from Table I that the isentropic shear associated with these occasions of turbulence was usually considerably greater than the normal, which for horizontal shear is about 0·08 hr.$^{-1}$ at these heights[1]. The isentropic shear is preferred to the horizontal shear as a parameter in turbulence analysis as lateral mixing, if existing, will tend to take place along isentropic surfaces[5].

Cases with no general shear in the vertical.—There was no general change of wind with height through the turbulent layer in approximately one quarter of the occurrences of bumps. In all these cases the turbulence was slight in intensity. In some of the cases the wind was fluctuating considerably with height about a general mean so that shears over depths of 1,400 ft. (the minimum depth over which shears could be measured) were quite large, though the shear over a depth of 3,000–4,000 ft. was small. Some cases occurred in broad wind maxima. As would be expected the Richardson numbers for these cases were mainly large, the mean of 19 cases in the troposphere being 9·2 and of 6 cases in the stratosphere, 28·5. The isentropic shears associated with these occasions of turbulence, for those cases where they could be estimated, were again usually considerably larger than normal, the mean of 11 cases in the troposphere being 0·19 hr.$^{-1}$.

Discussion.—In the cases occurring in a general change of wind with height the turbulence was presumably caused by the large shear in a manner resembling the way eddies are formed in the shearing layer near the earth's surface. The small values of Richardson number support this[6].

It is difficult to find a ready physical explanation of the turbulence which was not associated with vertical shear of wind. It is known that significant bumps can be caused only by vertical turbulent velocities, and perhaps it may be surmised that such turbulent velocities, in the absence of general shear in the vertical, can be caused by the degradation of considerably larger eddies rotating about almost vertical axes and perhaps several miles across, such as the eddies noted by Durst[7].

Other points which arose from the analysis were:—

(i) The turbulence did not appear to have affected either the temperature or the water-vapour distribution with height to any great extent.

(ii) Turbulence occurring in the stratosphere and in the absence of general wind change with height was usually associated with a low or trough in the circulation at about the 300-mb. level.

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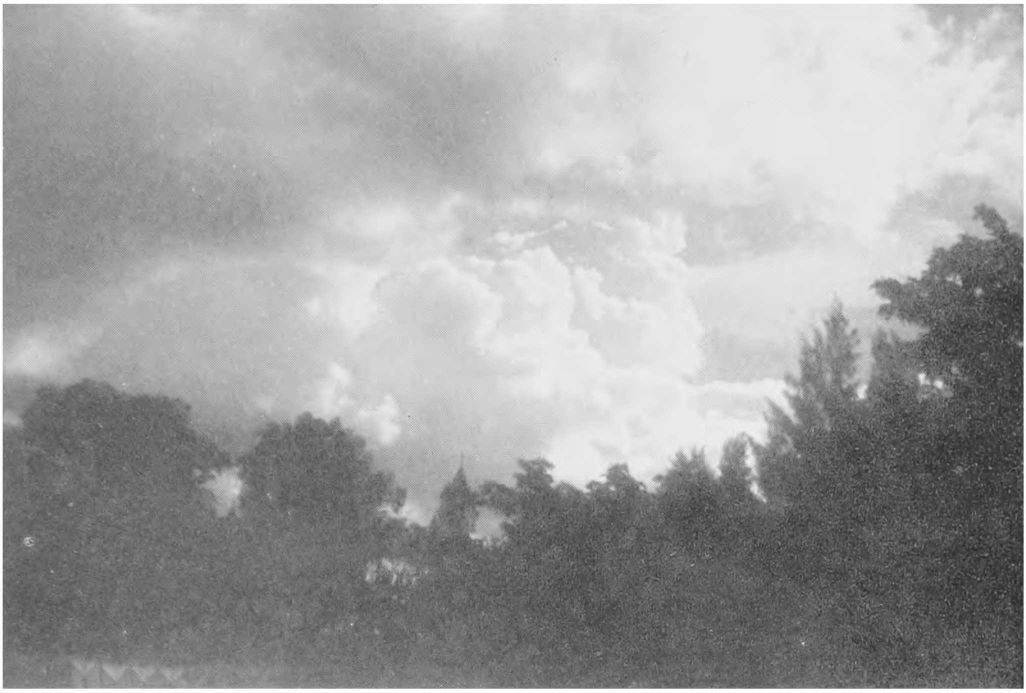
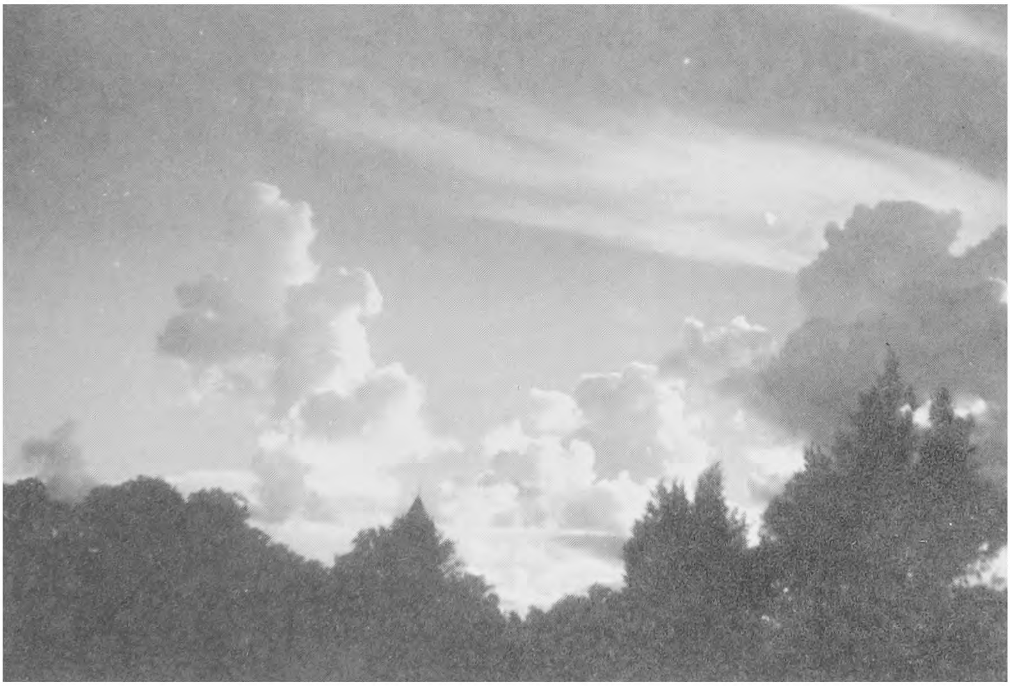


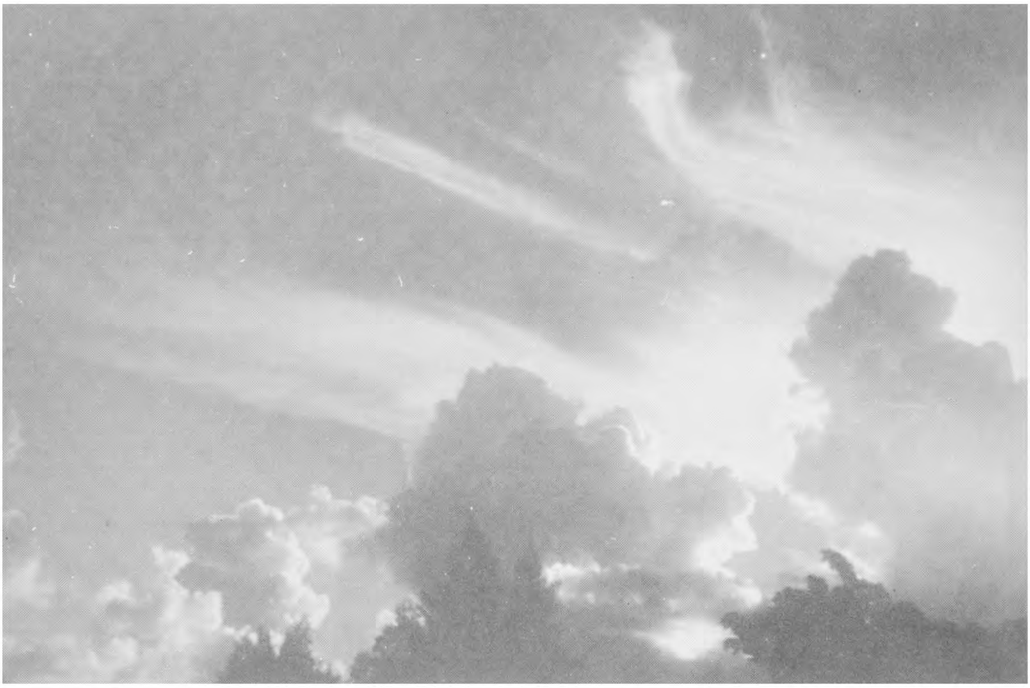
Photograph by the late Mr. M. C. Gillman

FIG. 1—CUMULUS DURING THE LATE AFTERNOON NEAR DAR-ES-SALAAM
(see p. 337)



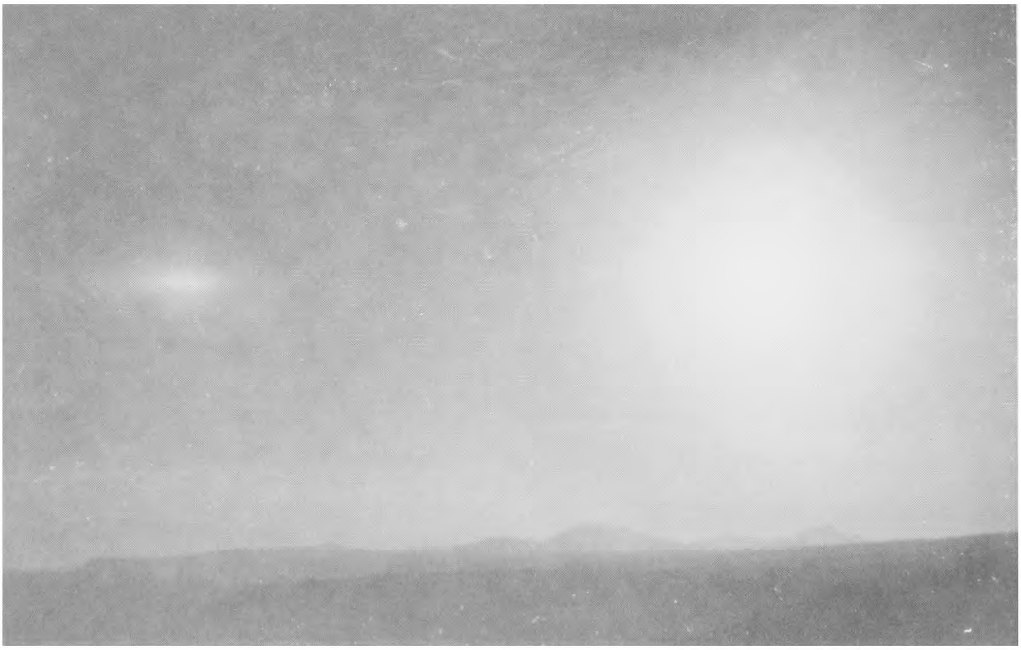
Photograph by the late Mr. M. C. Gillman

FIG. 2—GRADUAL DISPERSAL DURING THE EVENING OF CUMULUS CLOUD NEAR DAR-ES-SALAAM
(see p. 337)



Photograph by the late Mr. M. C. Gillman

FIG. 3—DISPERSAL OF CUMULUS CLOUD CAUSING FORMATION OF EXTENSIVE UPPER CLOUD (SHORTLY AFTER FIG. 2)



Reproduced by courtesy of J. B. Tuke

PHOTOGRAPH OF MOCK SUN TAKEN AT LYBSTER, CAITHNESS, MARCH 20, 1951

METEOROLOGY AT THE BRITISH ASSOCIATION

The annual meeting of the British Association was held this year in Edinburgh from August 8 to 15, under the presidency of H.R.H. The Duke of Edinburgh, K.G., F.R.S. As was appropriate to Festival Year the theme of the Presidential Address, and also of many of the addresses by section presidents, was a review of progress over the past 100 years.

In his presidential address to Section A (Mathematics and Physics) on August 9, Prof. Sir David Brunt, Secretary of the Royal Society, took as his title " A hundred years of meteorology, 1851–1951 " but covered more than two thousand years, tracing the development of meteorology from the time of Aristotle to the present day. He described the history of the Meteorological Office.from its foundation in 1855 as a department of the Board of Trade, and referred to the excellent example to the politicians given by meteorologists in the field of international co-operation since 1872. Weather pays no attention to iron curtains, the wind blows through and mainly from west to east. Of progress since 1945 Sir David considered that real progress had been made in radiation and cloud physics, but was somewhat sceptical of the value of the contributions in the field of kinematics and depression structure. In one important aspect, however, we were a long way behind the rest of the world—the study of meteorology at the universities. There was only one full department of meteorology in the whole of the British Commonwealth—at Imperial College, London.

Following this address Mr. R. Wilson gave the results of some spectrophotometric observations made at the Royal Observatory, Edinburgh, during the " blue sun " of September 26, 1950, caused by smoke from Canadian forest fires[1]. Comparison of the observations with those obtained under normal conditions led to the conclusion that the phenomenon was caused by the scattering of the sun's light by transparent particles, uniform in size and concentration. The relation between the diameter d (expressed in microns) and the refractive index m was found to be $d(m-1)=0{\cdot}519$. The average concentration of the particles was about 70 cm.$^{-3}$, and Mr. Wilson considered them to be globules of oil formed from the distillation of the wood in the forest fires. In addition, the results indicated the presence of some totally absorbing particles which were probably carbon.

The session on August 9 concluded with a paper by Mr. J. Paton on auroræ and luminous night clouds, illustrated with many beautiful slides. Four stations in Scotland make simultaneous photographs of auroræ from which can be determined their height and position. Similar measurements were made on noctilucent clouds on the night of July 10–11, 1949, placing them over the Shetland Isles at a height of 89 Km. The clouds were a vivid blue and were drifting westwards at 50–80 m.p.h.

The session on August 10 was devoted to a number of papers on " Natural and artificial production of atmospheric precipitation ". The first part of the session was honoured by the presence of H.R.H. The Duke of Edinburgh.

Mr. B. J. Mason opened with a paper on " The fundamental physics of precipitation processes in the artificial production of rain ". In the case of precipitation from layer clouds he considered the Bergeron-Findeisen process to be dominant. For convection clouds, raindrop growth by coagulation of cloud droplets may occur, but the conditions required were: a high concentration of cloud water (about 5 gm./m.^{3}), up-currents of about 5 m./sec. and a cloud depth of several kilometres, such as occur in the tropics. In temperate regions he considered that ice crystals were probably required initially. He then discussed the various experiments which had been made in the artificial stimulation of precipitation using dry ice, silver iodide and small water droplets. He deprecated the tendency there has been to draw spectacular conclusions from a few observations, and made a plea for more careful observation and control of the experiments. The most promising technique is that of seeding the cloud near the base with small water droplets of the order of 100μ diameter. Effective seeding with dry ice or silver iodide is confined to a very narrow range of cloud-top temperatures before natural seeding is likely to occur. On the possibility of large-scale effects, Mr. Mason pointed out that the energy that could be released by seeding is trifling compared with that required to build up a large-scale atmospheric disturbance.

Mr. F. H. Ludlam followed with a description of the calculations[2] he has carried out on the growth of raindrops starting with exceptionally large nuclei of concentration " 1 per roomful " and diameter 20–30μ. These he regarded as being formed from sea spray and was therefore doubtful whether they would be operative in any other than a maritime climate. He was more optimistic than Mr. Mason (and others) on the economic value of cloud seeding.

Mr. I. C. Browne then spoke of the work he is doing at Cambridge using a vertically looking 3-cm.-wave-length radar. The variations of echo intensity with height in precipitation are measured. Bands similar to the upper bands of echo seen by Dr. Bowen in Australia[3] are also seen at Cambridge, but are differently interpreted as being due to curved precipitation streaks. Ice (evidenced by the bright band on melting) was found to be present in all thunderstorms examined, and in the centre of a storm the echo intensity occasionally increased very steeply with decreasing height in a region well below the freezing level. This increase is interpreted as evidence of a chain reaction of drops growing and breaking in this region. Positive electric fields observed simultaneously are in accordance with the breaking-drop theory for electrification of rain.

Mr. R. F. Jones followed with a description of the work being done at East Hill using radar on 10-cm. and 3-cm. wave-lengths. Observations are made of all types of precipitation in an area extending to about 140 miles radius of East Hill. Different types of weather situation lead to different radar responses, the most striking being the difference between layer and shower clouds[4]. Aircraft observations show that in the layer clouds the reflecting particles above the freezing level are usually large ice crystals, often in the presence of supercooled water droplets. In shower clouds water drops predominate even at considerable heights above the freezing level. This led to the suggestion of two different methods of producing rain; in layer clouds by the Bergeron process and in convection clouds by coalescence of water droplets.

The formal papers were concluded by a paper from Dr. A. W. Brewer, read by Mr. H. P. Palmer. The opinion in Oxford, while recognizing that rain is formed in the tropics by coalescence, is that all raindrops in this country originate as ice crystals. As evidence of this was cited the reliability of the forecasting rule that temperatures at the tops of cumulus clouds must fall below about $-10°$C. before showers will occur. The difficulty that ice-forming nuclei were very rare at −10°C. was overcome by assuming that crystals formed on these nuclei during the rapid growth of the ice, fractures of the crystals occurred, and several " splinters " were formed. A chain reaction of " splinter " formation then produced all the ice crystals necessary for rain formation. Such " splinters " from rapidly growing ice crystals have been observed at Oxford.

The discussion which concluded the session was opened by Sir David Brunt who reinforced Mr. Mason's plea for more closely observed experiments in cloud seeding and deprecated the extravagant claims which had been made on the prospects of controlling the weather. He did not think that more than very local efforts could be achieved in this country, a view which was supported by Dr. A. H. R. Goldie.

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LETTERS TO THE EDITOR

Deepening of frontal depressions

Mr. Sumner's description of the storm of October 24, 1945, in the British Isles[1] lends support to his theory that the presence of instability in the vertical may be an important factor in the development of severe frontal depressions. In further support of his proposal I would like to make a somewhat similar set of observations in connexion with the development of the enormous storm which occurred over the eastern United States during November 1950 and its counterpart which occurred in November 1913. In the early stages of the development of the 1950 storm, during the afternoon and evening of November 24, thunderstorms were observed at several stations in eastern North Carolina and Virginia. Similarly, in the November 1913 storm the instability of the air in the warm sector was clearly indicated by the torrential flood-producing rains which occurred in eastern North and South Carolina during the earliest stages of the development of that storm on November 8.

Synoptic charts, drawn and analysed at the time that the instability was in evidence for the storms of 1950 and 1913, will be found in articles by Smith[2] and Mook[3] respectively.

C. P. MOOK

U.S. Weather Bureau, Washington National Airport,
Washington, D.C., August 30, 1951

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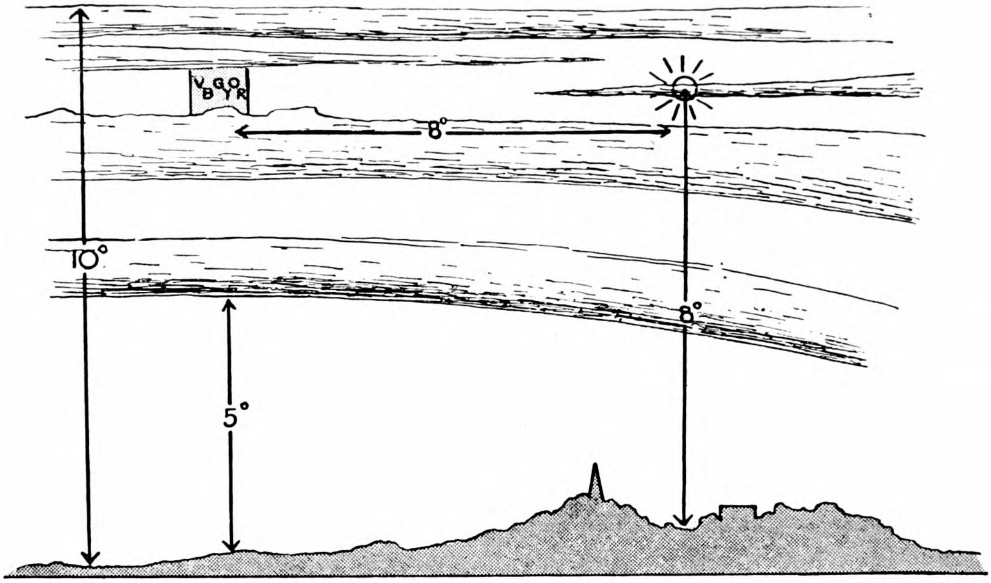
2. SMITH, C. D.; The destructive storm of November 25–27, 1950. *Mon. Weath. Rev., Washington D.C.,* **78,** 1950, Figs. 1 and 2, p. 204.
3. MOOK, C. P.; The famous storm of November, 1913. *Weatherwise, Philadelphia Pa.,* **2,** 1949, Figs. 1a and 1b, p. 126.

Rare optical phenomenon seen from Northolt

Whilst on observational duty at Northolt on August 5, 1951, I observed at 0528 G.M.T. an optical phenomenon (shown in the sketch below) as follows:—

A belt of high cloud stretched to the horizon in both directions, lying north-north-west to south-south-east and was apparently from 5° to 10° in altitude.



In one of several breaks was what appeared to be a section of a rainbow, at the same altitude as the sun and 8° to the left of it. The colouring was distinct and formed a complete spectrum, red being on the right; the apparent total width was about twice that of the sun, which was 8° above the horizon. The effect was that of a rainbow observed through a cloud break, although nothing was visible in the gaps either " above " or " below " the one in question. The phenomenon faded after about three minutes as the cloud formation slowly changed.

Conditions at the time were: surface wind calm, moderate to good visibility, but with ground fog patches on low ground to the north, trace of altocumulus at 16,000 ft., 3 oktas of cirrus, cirrocumulus and cirrostratus at about 22,000 ft.

JOHN G. SHIPCOTT

Northolt Airport, August 6, 1951

[It will be noted that the order of the colours of the phenomenon observed by Mr. Shipcott is that of a halo (refraction) and is the opposite to that of a corona (diffraction).

We are indebted to Mr. E. W. Barlow for the suggestion that the phenomenon was the rare halo of radius varying between 7°30′ and 10° or possibly a mock sun associated with that halo.

Besson[1] gives a list of six observations of this halo. The first report was by Van Buijsen[2] who observed it at Apeldoorn, Holland on April 6, 1892. A vivid description of its observation on May 11, 1915, in Florida is given by Andrus[3].

According to Humphreys[4] it requires the presence of pyramidal snow crystals which are rare.—Ed. *M.M.*]

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NOTES AND NEWS

Cumulus cloud development in east Africa

The photograph facing p. 316 was taken at sunset from a moving train in the area to the south-east of Lake Victoria. Heavy cumulus and cumulonimbus had developed over the land and the tops merged into a bank of really dense cirrus which thinned on its upper edge into a sheet of cirrostratus. During the night the lower portion of the convection cloud dissolved but there was much lightning in the residual upper portions.

The photograph facing p. 317 was taken shortly before sunset looking inland from Dar-es-Salaam. The cumulonimbus which developed in the late afternoon dissolved quite quickly during the evening without forming any appreciable residual cloud. This quick dispersion of well developed cloud is common during late May when weather conditions are beginning to reach the comparatively settled state of the SE. monsoon.

The photographs facing pp. 332 and 333 near Dar-es-Salaam were taken during the late afternoon (Fig. 1) and about two hours later (Figs. 2 and 3). The general cloud sequence is of maximum development inland during the afternoon and of gradual dissolution towards evening with the convection cloud giving rise to extensive upper cloud. The process is quite a slow one, as during April, when these photographs were taken, the weather over the area is definitely unsettled with considerable rainfall.

NEWS IN BRIEF

The L. G. Groves Memorial Prize for Meteorology has been awarded this year to Dr. R. C. Sutcliffe, O.B.E., Senior Principal Scientific Officer in the Meteorological Office, Dunstable, who has acquired a world-wide reputation by the many important papers he has published on the application of dynamical theory to weather forecasting. During the past year he has been the primary author of a paper which sets out the theoretical basis and the practical application of three-dimensional analysis to the forecasting of movement and development of pressure systems. This represents an important step in the science of forecasting. In addition to his personal contribution to the dynamical theory of forecasting, Dr. Sutcliffe, in his capacity as Assistant Director for Forecasting Research, has exercised a stimulating influence on many other important investigations which have been carried out by his team of research workers in the Napier Shaw Laboratory of the Meteorological Office.

Proxime accessit.—It was decided by the Selection Board that the name of Mr. A. C. Best, M.Sc., Principal Scientific Officer, Meteorological Office, Air Ministry, should be specially mentioned as researches carried out by him during the year were of outstanding merit.

The L. G. Groves Memorial Award for Meteorological Air Observers has been awarded this year to Flight Lieutenant D. Carlson, who has been employed continuously on meteorological air reconnaissance duties in Nos. 202 and 204 Squadrons for over three years. During this time he completed 61 sorties as a Meteorological Air Observer, involving 530 hours flying, often in difficult weather, and always showed great enthusiasm for his work. Flight Lieutenant Carlson has also carried out the duties of Squadron Meteorological Air Observer for two years. To his great credit a high level of efficiency has been achieved and maintained by the Observers in his Squadron. He has at all times set an excellent example on the ground and in the air, and his work and devotion to duty have been most praiseworthy.

METEOROLOGICAL OFFICE NEWS

A radio-sonde launched at Leuchars on September 4 was recovered, four days later, from the bed of the North Sea by the trawler *Drumaston* (Skipper, David Liston). The instrument was lying in about 45 fathoms, and was roughly 100 miles east of Leuchars. By a coincidence, the mate of the vessel, Mr. J. Angus, who actually found the radio-sonde, is a neighbour of Mr. B. V. Bishop of the Meteorological Office, Pitreavie, so that the instrument quickly found its way back to the Instruments Division, but, of course, after its immersion in sea water it was entirely useless.

In the annual sports of the Gloucester and District Civil Service Association a team representing the Meteorological Office, Air Traffic Control Centre, Gloucester, secured third place—a remarkable feat since the office was much the smallest Department competing, and had not previously succeeded in raising a team. Mr. E. B. Jefferies was second in the 440 yards, and a team was third in the 4 × 110 yards relay. Representatives of the Office also won first and third places in both the veterans' race and the egg-and-spoon race. A tug-of-war team also entered, but was defeated by Post Office Engineers.

WEATHER OF SEPTEMBER 1951

Mean pressure was between 1015 and 1020 mb. over western Europe, and between 1010 and 1015 mb. over most of Scandinavia and the British Isles. Mean pressure fell below 1010 mb. to the north and west of the British Isles, including the North Atlantic Ocean north of latitude 50°. Over North America mean pressure was generally between 1010 and 1020 mb.

Over the North Atlantic just west of the British Isles, mean pressure was 5–10 mb. below normal, and over the British Isles and south-west Europe it was 2–5 mb. below normal. Over Scandinavia mean pressure was a little above normal, the excess being between 1 and 3 mb.

Mean temperature was between 50° and 60°F. over the British Isles, increasing to 60–70°F. over Europe, 70–75°F. over the Mediterranean region and 80–90°F. over north Africa. Temperature was generally about 3–4°F. above normal in these areas.

In the British Isles the weather was rather warm generally. Broadly speaking it was dry in north and east Scotland, parts of northern England and locally in Northern Ireland, and wet elsewhere. Sunshine was below the average except in east Scotland, where there was an appreciable excess.

In the opening days a depression off north-west Scotland moved slowly east-north-east and filled, while small secondary depressions moved quickly east-north-east along the English Channel. Heavy rain and local thunderstorms occurred in the south of England on the 1st and at Guernsey again on the 2nd. On the 3rd and 4th a very deep depression moved rather quickly north-east from mid Atlantic and gales were recorded locally on our north-west coasts on the 4th. Meanwhile an associated trough moved north-east across the British Isles causing rain generally, which was considerable locally in the west. Associated with this depression a warm air stream from south of Bermuda crossed England and Wales, and temperature rose to 75°F. at a number of places in eastern England on the 4th and touched 79°F. at Gorleston and Mildenhall and 77°F. at Finningley and Spurn Head. Thereafter a weak trough moved very slowly south-east over England giving rain in east and south-east England and the Midlands. Rainfall was very variable; at Oxford a fall of 3·34 in. was registered during heavy thunderstorms on the night of the 6th–7th. Temperature continued high and reached 78°F. at Tangmere on the 6th. Between the 6th and the 9th an anticyclone moved north-east across Scotland to Scandinavia and a spell of mainly fair weather prevailed, though local thunderstorms occurred in the south-west on the 9th. A very unsettled spell ensued from the 11th to the 14th, when a deep almost stationary depression was situated to the south-west of Iceland. On the 11th and 12th a trough associated with this depression moved slowly east across the British Isles and rain fell in most parts but it was rather scattered in the south of England. On the 13th a vigorous secondary off south Ireland moved rapidly north-north-east and on the 15th another disturbance (originally a tropical hurricane) moved quickly north-east across England to the Baltic. During this spell rain occurred daily and was heavy locally at times (2·35 in. at Fort William and Thirlmere on the 14th) and thunderstorms were recorded in some places on the 12th and 13th. Strong winds, reaching gale force locally in the west, were recorded on the 13th. Subsequently an anticyclone off the west of Ireland moved south-east, later turning east-north-east across England to Germany, and a period of settled weather occurred apart from slight rain at times in the extreme west and north. The fair spell was broken on the 22nd when a depression to the south-west of the British Isles moved north and became almost stationary off the west of Scotland. Secondary disturbances swinging round the main centre caused rain generally, heavy locally at times (4·53 in. at Thirlmere on the 24th and 2·16 in. at Bradford and 2·14 in. at Dorchester on the 27th). On the 28th a ridge of high pressure moved east over the British Isles and on the 29th it became joined to an anticyclone centred near Leningrad; fair weather, apart from scattered showers, prevailed on the 28th and fair weather with morning fog persisted on the mainland of Great Britain until the end of the month.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	80	31	+1·6	141	+1	79
Scotland	73	28	+1·4	87	−2	103
Northern Ireland ...	71	36	+1·6	97	0	81

RAINFALL OF SEPTEMBER 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·57	141	*Glam.*	Cardiff, Penylan ...	5·37	176
Kent	Folkestone, Cherry Gdn.	5·34	225	*Pemb.*	Tenby	3·89	123
,,	Edenbridge, Falconhurst	3·88	171	*Card.*	Aberystwyth	..	..
Sussex	Compton, Compton Ho.	3·39	122	*Radnor*	Tyrmynydd	5·17	134
,,	Worthing, Beach Ho. Pk.	3·46	162	*Mont.*	Lake Vyrnwy	6·14	170
Hants.	Ventnor, Cemetery ...	4·26	168	*Mer.*	Blaenau Festiniog ...	14·74	187
,,	Bournemouth	3·25	139	*Carn.*	Llandudno	2·66	125
,,	Sherborne St. John ...	3·61	176	*Angl.*	Llanerchymedd ...	5·83	198
Herts.	Royston, Therfield Rec.	2·20	117	*I. Man*	Douglas, Borough Cem.	5·27	161
Bucks.	Slough, Upton... ...	3·15	179	*Wigtown*	Port William, Monreith	3·95	135
Oxford	Oxford, Radcliffe ...	4·92	288	*Dumf.*	Dumfries, Crichton R.I.	4·13	152
N'hants.	Wellingboro', Swanspool	1·27	71	,,	Eskdalemuir Obsy. ...	6·90	186
Essex	Shoeburyness	4·29	257	*Roxb.*	Kelso, Floors	1·39	73
,,	Dovercourt	2·93	164	*Peebles*	Stobo Castle	2·44	97
Suffolk	Lowestoft Sec. School ...	1·87	95	*Berwick*	Marchmont House ...	1·49	62
,,	Bury St. Ed., Westley H.	3·42	172	*E. Loth.*	North Berwick Res. ...	·73	35
Norfolk	Sandringham Ho. Gdns.	2·63	127	*Midl'n.*	Edinburgh, Blackf'd. H.	·88	43
Wilts.	Aldbourne	3·83	192	*Lanark*	Hamilton W. W., T'nhill	2·99	112
Dorset	Creech Grange... ...	4·54	166	*Ayr*	Colmonell, Knockdolian	3·06	88
,,	Beaminster, East St. ...	4·29	168	,,	Glen Afton, Ayr San ...	6·16	158
Devon	Teignmouth, Den Gdns.	4·31	220	*Bute*	Rothesay, Ardencraig...	4·51	111
,,	Cullompton	4·00	178	*Argyll*	Morvern, Drimnin ...	6·27	111
,,	Ilfracombe	2·85	106	,,	Poltalloch	4·23	93
,,	Okehampton, Uplands	4·53	140	,,	Inveraray Castle ...	7·05	110
Cornwall	Bude, School House ...	2·53	102	,,	Islay, Eallabus... ...	3·89	93
,,	Penzance, Morrab Gdns.	4·24	145	,,	Tiree	3·77	102
,,	St. Austell	4·76	149	*Kinross*	Loch Leven Sluice ...	2·26	88
,,	Scilly, Tresco Abbey ...	3·18	124	*Fife*	Leuchars Airfield ...	1·40	73
Glos.	Cirencester	3·27	149	*Perth*	Loch Dhu	6·89	120
Salop	Church Stretton ...	2·54	120	,,	Crieff, Strathearn Hyd.	3·05	107
,,	Shrewsbury, Monksmore	1·98	121	,,	Pitlochry, Fincastle ...	..	..
Worcs.	Malvern, Free Library	2·89	150	*Angus*	Montrose, Sunnyside ...	1·46	73
Warwick	Birmingham, Edgbaston	3·34	187	*Aberd.*	Braemar	1·82	73
Leics.	Thornton Reservoir ...	1·36	75	,,	Dyce, Craibstone ...	1·25	52
Lincs.	Boston, Skirbeck ...	2·03	115	,,	Fyvie Castle	·68	26
,,	Skegness, Marine Gdns.	1·88	104	*Moray*	Gordon Castle	·66	26
Notts.	Mansfield, Carr Bank ...	1·72	94	*Nairn*	Nairn, Achareidh ...	·63	30
Derby	Buxton, Terrace Slopes	3·42	106	*Inverness*	Loch Ness, Garthbeg ...	1·76	57
Ches.	Bidston Observatory ...	2·29	95	,,	Glenquoich	7·16	83
Lancs.	Manchester, Whit. Park	2·99	126	,,	Fort William, Teviot ...	8·56	134
,,	Stonyhurst College ...	3·18	83	,,	Skye, Duntuilm ...	3·96	86
,,	Squires Gate	3·05	113	*R. & C.*	Tain, Tarlogie House ...	·93	41
Yorks.	Wakefield, Clarence Pk.	2·39	149	,,	Inverbroom, Glackour...	2·64	60
,,	Hull, Pearson Park ...	1·07	62	,,	Applecross Gardens ...	5·40	108
,,	Felixkirk, Mt. St. John	2·66	146	,,	Achnashellach	6·43	93
,,	York Museum	1·77	109	,,	Stornoway Airfield ...	2·27	61
,,	Scarborough	·97	54	*Suth.*	Loch More, Achfary ...	..	..
,,	Middlesbrough... ...	·84	51	*Caith.*	Wick Airfield	1·44	58
,,	Baldersdale, Hury Res.	1·84	74	*Shetland*	Lerwick Observatory ...	2·58	86
Norl'd.	Newcastle, Leazes Pk....	·98	50	*Ferm.*	Crom Castle	2·94	105
,,	Bellingham, High Green	2·13	89	*Armagh*	Armagh Observatory ...	1·89	77
,,	Lilburn Tower Gdns. ...	·83	35	*Down*	Seaforde	3·21	117
Cumb.	Geltsdale	4·08	146	*Antrim*	Aldergrove Airfield ...	2·61	105
,,	Keswick, High Hill ...	8·77	207	,,	Ballymena, Harryville...	2·42	78
,,	Ravenglass, The Grove	5·61	166	*L'derry*	Garvagh, Moneydig ...	2·75	93
Mon.	Abergavenny, Larchfield	4·58	196	,,	Londonderry, Creggan	..	..
Glam.	Ystalyfera, Wern House	7·56	173	*Tyrone*	Omagh, Edenfel ...	3·27	107

M.O. 548 AIR MINISTRY

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A FEBRUARY CROSS-SECTION ALONG THE GREENWICH MERIDIAN

By R. W. JAMES, M.Sc.

Summary.—Techniques in the construction of meridional profiles of geostrophic westerly wind are briefly discussed. It is shown that computations may be greatly reduced by plotting the contour height of a fixed pressure level against the cosine of latitude. The technique is applied to obtain the mean westerly wind profile for February 1951, considered to be typical of the east Atlantic.

Comparison is made with corresponding profiles drawn for east America. It is suggested that the apparent differences may be attributed to the different boundary conditions involved in a sea and land surface, respectively.

Introduction.—Cross-sections of the mean westerly geostrophic flow have been drawn for the United States (notably by Hess[1]), the Australasian region[2,3], China[4] and India[5]. The northern-hemisphere sections are for broadly similar topographic regions; a land mass to windward with a prominent mountain barrier, the Rockies in the case of the United States, the Himalayas in the Asiatic regions. The Australasian sections, on the other hand, may be regarded as typical of maritime areas.

It would be hazardous to discuss the differences between land and sea profiles by comparing the northern- and southern-hemisphere sections, for, in addition to contrasting boundary conditions, we have to contend with possible inherent differences in the mean flow in the two hemispheres. It would, therefore, be of interest to compare a northern-hemisphere cross-section of windward oceanic aspect with the existing profiles proper to a continental exposure.

The Greenwich meridian has the broad Atlantic to windward, the British Isles presenting a relatively small land mass, so that this cross-section might be taken as typical of a sea exposure. It might appear surprising that no cross-section for this meridian has yet been published, considering the wealth and accuracy of the available aerological material.

It may be that some diffidence arises from doubts as the homogeneity of the available ascents, for the cross-section lies over different countries, with differing sounding equipment. It is true that any definitive cross-section must be based on a critical comparison of the performance of the varying radio-sondes employed, but for a first attempt it seems reasonable enough to dispense with such refinements.

We shall present below a cross-section of geostrophic westerly wind along the Greenwich meridian for February 1951. The data are extracted from *Monthly*

Climatic Data for the World (February 1951)[6]. This publication includes a selection of the mean values of the upper air elements contained in the monthly CLIMAT TEMP broadcasts of many countries. No European country as yet publishes upper air climatological summaries.

The purpose is not merely to present a particular cross-section but rather to indicate how easily such sections can be drawn, given the aerological data in suitable form. The actual labour of drawing the cross-section below occupied less than a day.

"Elimination" of latitude.—The earlier cross-sections[1] were computed from data embodying mean pressures at fixed height levels. Most meteorological services now publish their material in terms of the mean height of specific pressure levels. The advantages of working with contour heights rather than pressures when geostrophic wind speed is required are obvious. Not only is the effect of change of density with height eliminated, but also the smaller influence of the change of density at a fixed level with latitude.

However, with the usual techniques correction must still be made for the change of the Coriolis parameter with latitude. We shall now see how this variation in latitude may be treated in a particularly simple way.

The expression for the westerly component of geostrophic wind speed is

$$U_g = \frac{g}{2\omega \sin\varphi} \frac{\partial Z}{\partial y} \qquad \ldots\ldots (1)$$

where g is the acceleration of gravity, ω is the earth's rotational speed, Z is the contour height of a given pressure level, and y is the distance along a meridian. We may write $y = -a\varphi$, where a is the earth's radius, and eliminating y in equation (1) we find

$$U_g = \frac{g}{2\omega a} \frac{\partial Z}{\partial \cos\varphi} \qquad \ldots\ldots (2)$$

Therefore, we may plot the contour height against the cosine of the latitude instead of the latitude itself, and the slope of the curve at any point is a measure of geostrophic westerly wind speed. Numerically we have, when Z is expressed in hundreds of metres,

$$\begin{aligned} U_g &= 1{\cdot}06 \frac{\partial Z}{\partial \cos\varphi} \\ &\simeq 1{\cdot}06 \frac{\Delta Z}{\Delta \cos\varphi} \text{ m./sec.} \end{aligned} \qquad \ldots\ldots (3)$$

where ΔZ is the difference in contour height between two points φ_2 and φ_1, $\Delta\cos\varphi = \cos\varphi_2 - \cos\varphi_1$. A smoothed curve can be drawn through the available data and the slopes read off at any desired number of points, or we may form the differences ΔZ and $\Delta\cos\varphi$ for a pair of stations and so determine the mean U_g between them.

Which method is adopted depends largely on convenience, but the writer prefers to estimate the slope. To use it as a matter of routine one requires paper ruled proportionately to the cosine.

No particular novelty is claimed for this technique. Mr. Radok says that he and Loewe employed it in computing their southern-hemisphere cross-sections[2].

Contour height as a function of latitude.—Table I shows the contour heights of the 850-, 700-, 500-, 300- and 200-mb. levels in February 1951 for the nine stations used in the analysis, ranging from Lerwick (latitude 60°N.) to Dakar (15°N. approximately). All the stations except Dakar are less than 10° from the Greenwich meridian.

TABLE I—MEAN CONTOUR HEIGHT OF SELECTED PRESSURE LEVELS, FEBRUARY 1951

	Position		Pressure levels (mb.)				
			850	700	500	300	200
					metres		
Lerwick	60°11′N.	1°11′W.	1,267	2,769	5,240	8,672	...
Larkhill	51°11′N.	1°48′W.	1,321	2,831	5,319	8,771	11,299
Brest	48°27′N.	4°25′W.	1,329	2,844	5,330	8,789	11,415
Bordeaux	44°50′N.	0°42′W.	1,384	2,909	5,423	8,908	11,517
Gibraltar	36°09′N.	5°21′W.	1,496	3,054	5,636	9,226	11,834
Casablanca... ...	33°35′N.	7°39′W.	1,524	3,083	5,664	9,275	...
Colomb-Béchar ...	31°40′N.	2°10′W.	1,524	3,134	5,691	9,317	11,935
Aoulef	27°04′N.	1°06′E.	1,517	3,108	5,734	9,391	12,051
Dakar	14°40′N.	17°26′W.	1,512	3,126	5,797	9,526	12,220

Fig. 1 shows the 850-mb. heights plotted against the cosine of the latitude. It will be seen that a reasonably smooth curve results, and that the change in slope at about latitude 32·5°N. indicates that this latitude marks the division between the westerly flow of middle latitudes and the tropical easterlies in the 850-mb. surface. The slope of the curve is almost constant between latitudes 35°N. and 47°N., and is greater here than elsewhere. This indicates that the mean zonal wind speed at the 850-mb. level is almost uniform over a very broad band of latitude, that is, the wind maximum is very flat or the mean jet stream is very diffuse. Around latitude 50°N. there is a considerable reduction in the slope of the curve, and hence of the corresponding geostrophic wind speed. One might feel tempted to attribute this abrupt change to the transition from French to

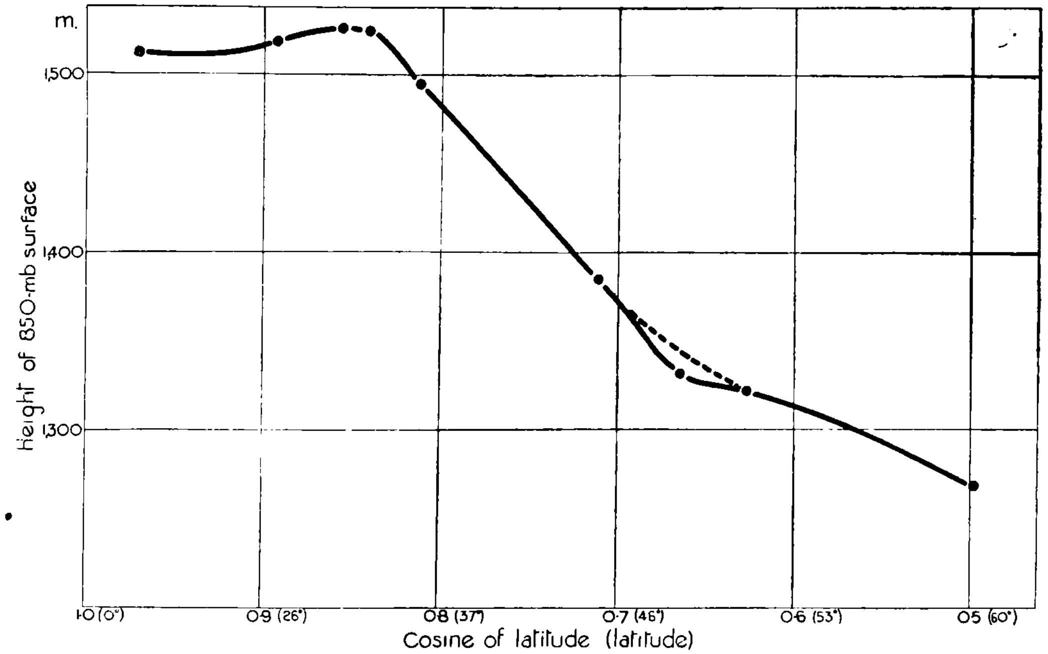

FIG. 1—RELATION BETWEEN HEIGHT OF 850-MB. SURFACE AND COSINE OF LATITUDE ALONG THE GREENWICH MERIDIAN

British ascents. This slope minimum could be eliminated by smoothing, as indicated by the broken line.

Fig. 2 shows the corresponding curve for 300 mb. The easterlies are absent at this level. One distinguishes a maximum of slope between Gibraltar (36°N.) and Bordeaux (44°50′N.); the "jet-stream latitude" at 300 mb. may be taken as approximately 37°N. The speed maximum is again very broad, and there is again a suggestion of minimum slope between Brest and Larkhill, which may be spurious.

The general impression gained by a study of the curves is that a consistent smooth curve can be drawn through the data, and that the slope of this curve can readily and rapidly be evaluated to give the mean geostrophic westerly component.

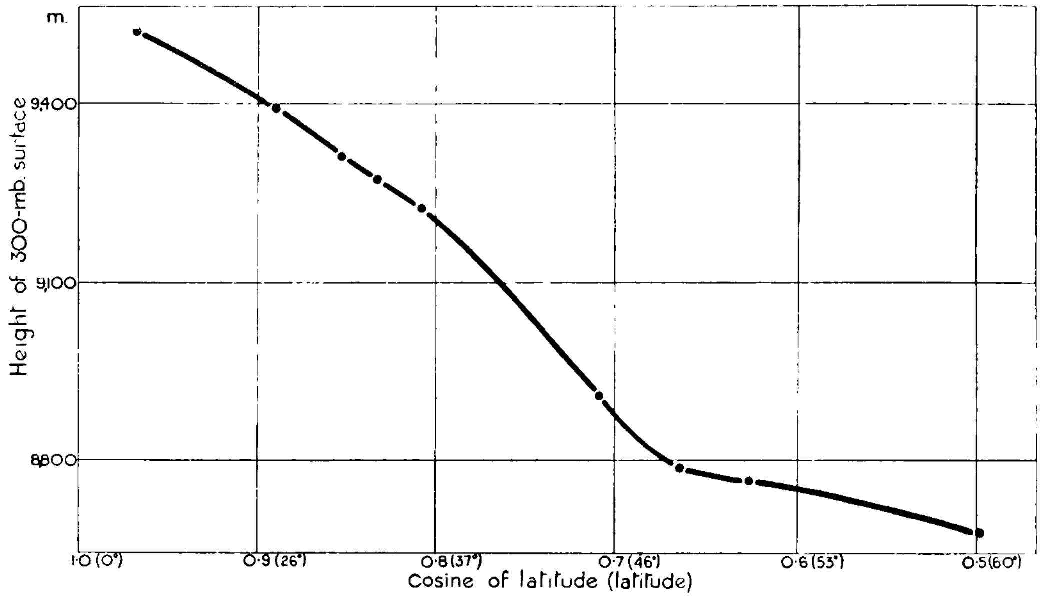

FIG. 2—RELATION BETWEEN HEIGHT OF 300-MB. SURFACE AND COSINE OF LATITUDE ALONG THE GREENWICH MERIDIAN

Geostrophic-wind profile.—Curves of height against cos φ were drawn for the 850-, 700-, 500-, 300- and 200-mb. levels, and the slopes read off for selected values of φ. The corresponding wind speeds were obtained from the expression (3), and from these figures the geostrophic-wind profile cross-section shown in Fig. 3 was drawn.

Normally the height is taken as the vertical axis in such a cross-section. This is appropriate when the analysis is in terms of pressure at a fixed height, but in contour analysis it is more natural to use pressure as the ordinate. To make this co-ordinate correspond as closely as possible with the actual height we have used the logarithm of pressure. It is not difficult to display the wind speed as a function of the actual height, if this is desired, but slightly more computation is involved, and the distortion involved is so slight as to be inappreciable on inspection. In any event, since wind speeds are normally quoted at fixed levels, the presentation used here is the more appropriate. The latitude is taken as the spatial co-ordinate. We could equally well have employed cos φ when the low-latitude end of the scale would have been compressed relative to the high-latitude end.

A glance at Fig. 3 reveals that the W.-wind profile along the Greenwich meridian in winter resembles the winter profiles found in other parts of the world. There is a flat maximum (mean jet) in about latitude 40°N. Over the North American continent the winter maximum occurs in about latitude 37°N., with a subsidiary jet stream in latitude 55°N. There is no evidence of this subsidiary in the Greenwich cross-section, unless the flat maximum may be regarded as a coalition of the two jet streams.

There are other differences between the two cross-sections. Over North America the wind maximum occurs near the 200-mb. level, whereas on the European seaboard the maximum is closer to 300 mb.

Unfortunately the surface geostrophic-wind profile for west Europe is not available, but the evidence points to an approximate four-fold increase in geostrophic wind speed between the surface and the jet-stream level. This corresponds to the structure found by Loewe and Radok[2], and by Hutchings[3], for maritime areas of the southern hemisphere. On the other hand, over North America there is something like an eight-fold increase in speed between the surface and the jet-stream level, and this ratio holds also for the Chinese cross-section[4]. In addition, the jet-stream speed is less over Europe than over North America, 35m./sec., as against 45m./sec.

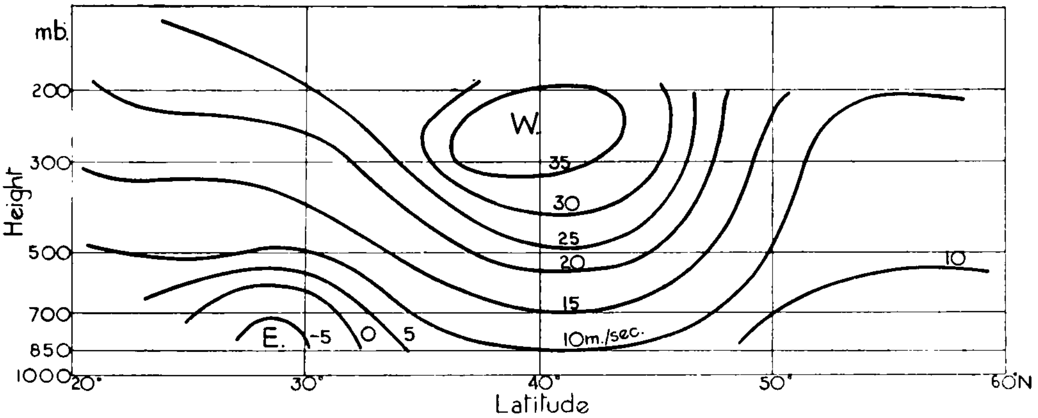

FIG. 3—ISOPLETHS OF MEAN ZONAL WIND VELOCITY

In a paper accepted for publication shortly in *Tellus*, the author presents evidence that these differences in the mean westerly flow are characteristic of land and oceanic regions respectively. The stronger westerlies aloft and the stronger gradient of mean westerly wind with height over the land may be taken as evidence of the greater dissipation of westerly momentum by skin friction. Since a land area represents a stronger sink of westerly angular momentum, the transport downwards of momentum must be strongest over the land. This is facilitated by stronger westerlies aloft and a greater gradient of momentum with height.

The wind profile for February 1951 is not necessarily typical of the mean winter structure over the east Atlantic, and it is highly desirable to have seasonal mean profiles. The present profile is offered simply as an illustration of the ease with which such diagrams can be constructed when the upper air climatological data are available.

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UNEXPECTED FAIR WEATHER OVER SOUTHERN SCOTLAND, MARCH 10, 1951

By W. D. S. McCAFFERY, B.Sc.

Summary.—The afternoon and evening of Saturday, March 10, 1951, was unexpectedly fine over much of southern Scotland and northern England. The fine weather can be attributed to the movement of a "bubble" of dry air. The detachment of this bubble from a reservoir in the Iceland area and its subsequent history are described.

Synoptic situation.—The 0900 G.M.T. chart for March 10, 1951 (Fig. 1), showed practically clear skies at Renfrew, Prestwick, West Freugh, Isle of Man and over much of Ireland. Over the remainder of the British Isles, weather was mainly cloudy with some fog patches, drizzle, sleet and snow showers over England and Wales, and snow or snow showers over Scotland.

The precipitation over England fell from a fairly thick layer of stratus and stratocumulus cloud which had moved westwards in the easterly air stream between an anticyclone over Norway and a complex depression over the Bay of Biscay and France (Fig. 2). There was probably little or no medium cloud. The Larkhill and Downham Market upper air ascents were dry above 700 mb., and there was a pronounced inversion at 850 mb., which would limit the depth of the cloud layer. The snow which fell over most of Scotland was associated with a polar depression centred approximately over the Isle of Skye. Both the Lerwick and Stornoway upper air ascents for 0900 G.M.T. were conditionally unstable and fairly moist up to at least 500 mb., and solid cloud of cumulonimbus or nimbostratus type could be expected. The Leuchars ascent was unstable up to about 650 mb. The problem for the forecaster was to find a satisfactory explanation for the area of clear skies and to forecast future developments.

Before 0900 it had been expected that the polar low would move south-south-west from the Moray Firth and that an easterly or south-easterly gradient wind would re-establish itself over the whole of Scotland except the extreme south-west, bringing to all east Scotland cloudy conditions, with occasional snow flurries in coastal areas, and more prolonged snowfall over the windward slopes of the hills. By the time the 0900 chart was ready for analysis, the cloud sheet over south-east Scotland had begun to break up from the west and snow had ceased at Silloth and Eskdalemuir, and by 1200 had also ceased at St. Abb's Head. Analysis of the 0900 chart showed that the polar low was now moving

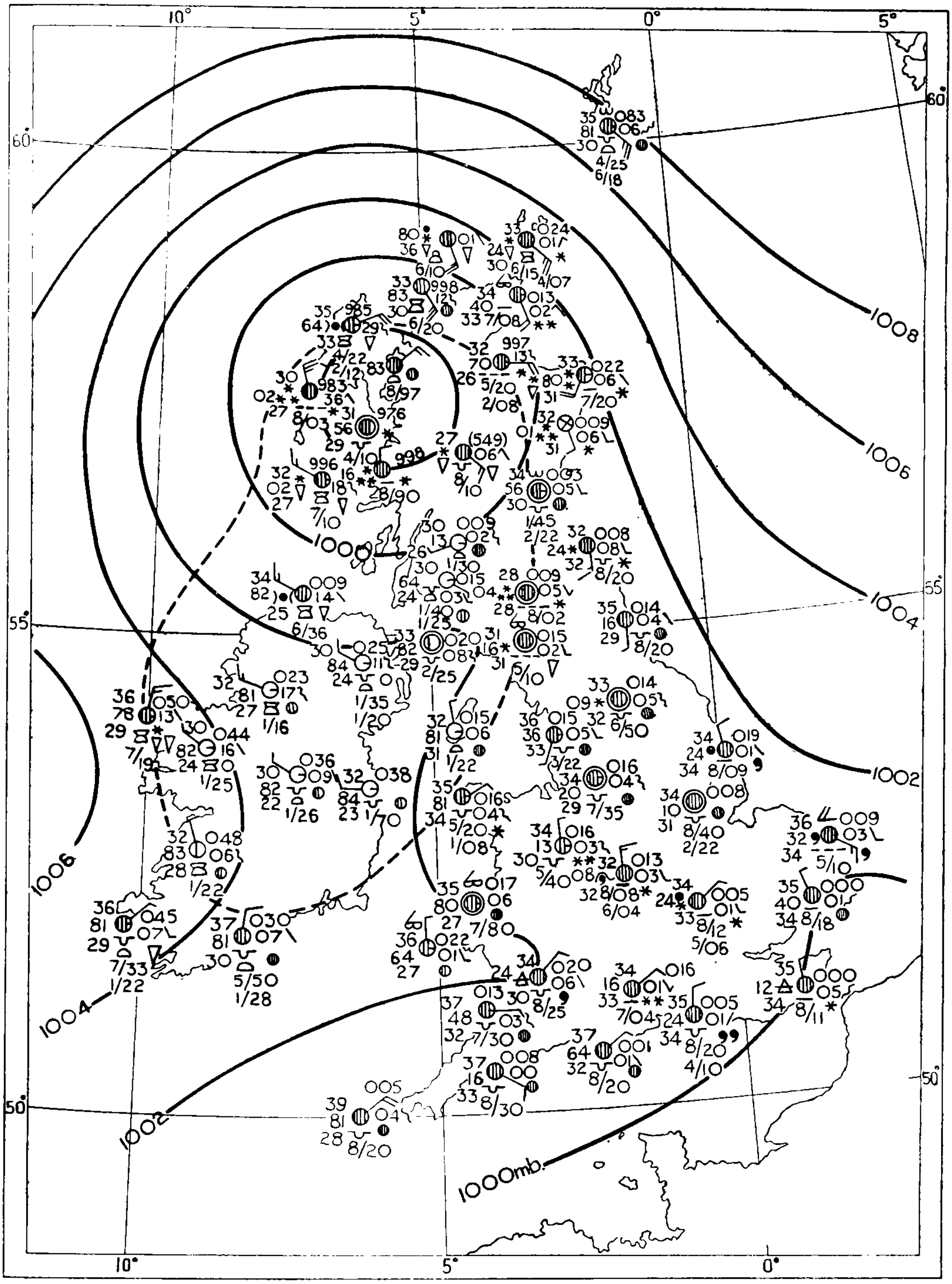

10°
5°
0°
5°
60
55
50
1008
1006
1004
1002
1000mb.
1006
1004
1002
998
997
996
1000

FIG. 1—SYNOPTIC CHART, 0900 G.M.T., MARCH 10, 1951
The boundary of the drier air is shown by the broken line.

only just slightly south of west (Fig. 2) with a fairly definite circulation, consequently the westerlies to the south of the centre could be expected to continue to affect south Scotland for at least several hours. In fact, the clear skies observed in the south-west at 0900 spread eastwards to a line from Aberdeen to St. Abb's Head, before retreating westwards as a south-easterly gradient wind became established during the following night.

Dew points within this area of clear skies fell very low (14°F. at Turnhouse at 1500 for example), while the 1500 upper air ascent at Leuchars showed a dew point of 3°F. at 900 mb. with an air temperature of 33°F. At 800 mb. on the same ascent, the corresponding temperatures were 9°F. and 12°F. respectively. The clear skies were apparently associated with a shallow surface layer of very dry air.

On the 0900 chart a line of demarcation can be drawn between dew points of about 30°F. or above and those below 30°F. and mainly around 25°F. (Fig. 1). This line runs from Benbecula to Kinloss, Leuchars, Silloth, Isle of Man, Shannon and Blacksod Point. From Kinloss to south of Silloth the line has the characteristics of a front, and indeed, the cessation of snowfall and clearance of cloud from the west, and its subsequent return from the east during the night and next day, can be explained on that basis. Mr. C. K. M. Douglas comments:

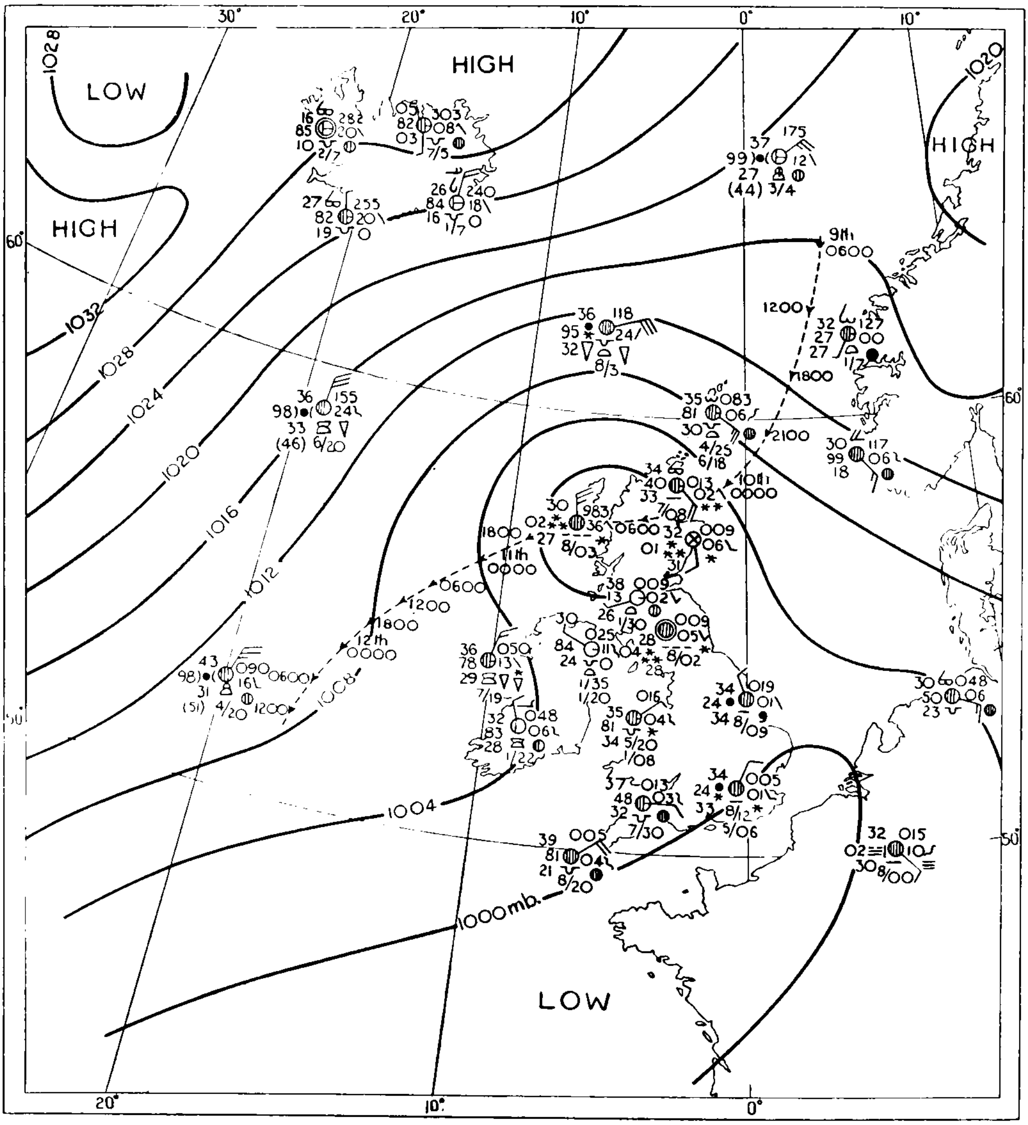
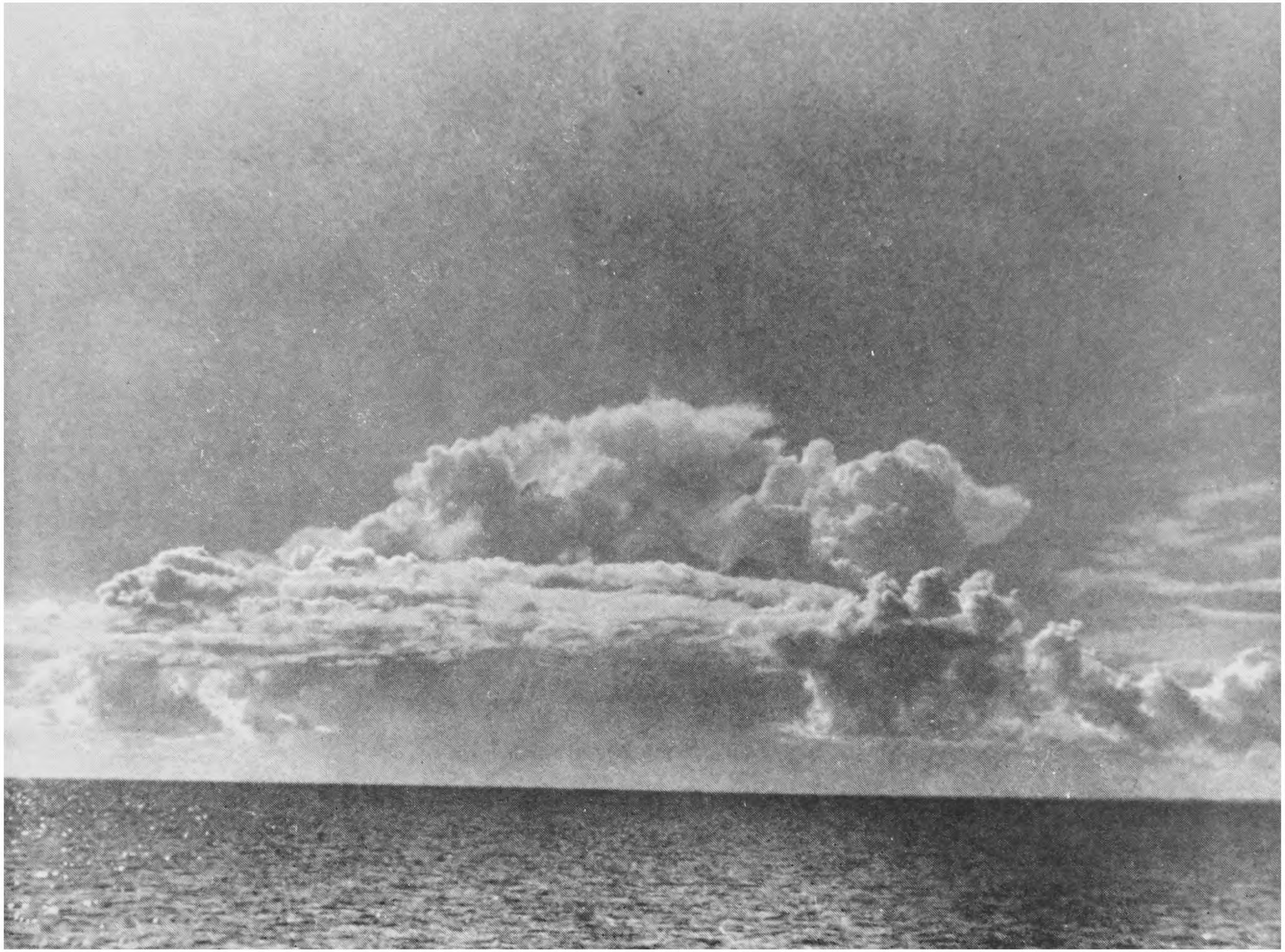

30°
20°
10°
0°
10°
HIGH
LOW
HIGH
HIGH
LOW
1028
1032
1028
1024
1020
1016
1012
1004
1000mb.
1020
60°
50°
20°
10°
0°
9th
0600
1200
1800
2100
10th
0000
0600
1200
1800
11th
0000
0600
1200
1800
12th
0000
0600
1200

FIG. 2—SYNOPTIC CHART, 0900 G.M.T., MARCH 10, 1951

The movement of the polar low between 0600, March 9, and 1200, March 12, is shown by the broken line.

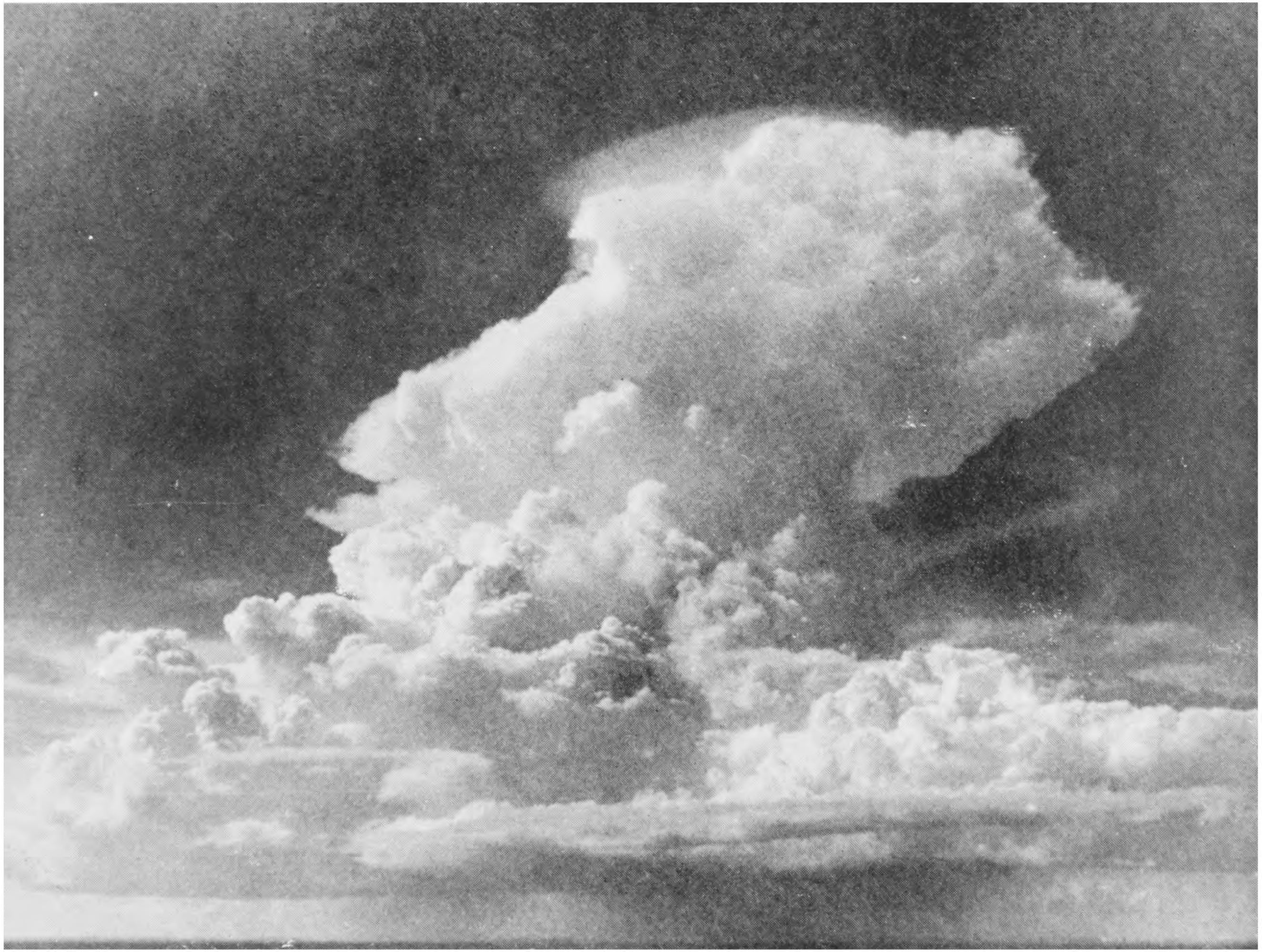
[*To face p. 348*



Photograph by the late Mr. M. C. Gillman

CUMULONIMBUS CLOUDS OVER LAKE VICTORIA
(see p. 367)

To face p. 349]



Photograph by the late Mr. M. C. Gillman

CUMULONIMBUS CLOUDS OVER LAKE VICTORIA
(see p. 367)

"The sequence of temperature and humidity observations at Leuchars and the wind structure showed that there was undercutting by the cold air, i. e. the slight rain was of a cold-front type although there was no historical cold front. Subsidence behind a cold front is frequent even in a depression in a region of cyclonically curved isobars. In this case the col was not too far to southward and the dryness extended to Liverpool in the col area at 2100." It should be noted that subsidence was occurring in the lower levels of the atmosphere over an area of steadily falling surface pressure.

Although the cessation of snowfall and the clearing skies over south Scotland and parts of Ireland and north-west England can be explained by the introduction of a cold front, the subsequent development of the area of low surface dew points and, on careful examination, the events leading up to the situation on March 10, described above, indicate that this is not the whole explanation. The history of events appears to be as follows.

Previous synoptic history.—At 0000 G.M.T. March 8, 1951 (Fig. 3), cold air with dew points 25–27°F. was flowing west-south-westwards over the O.W.S. *Polar Front* (66°N., 2°E.) and Iceland. This stream of air lay to the north

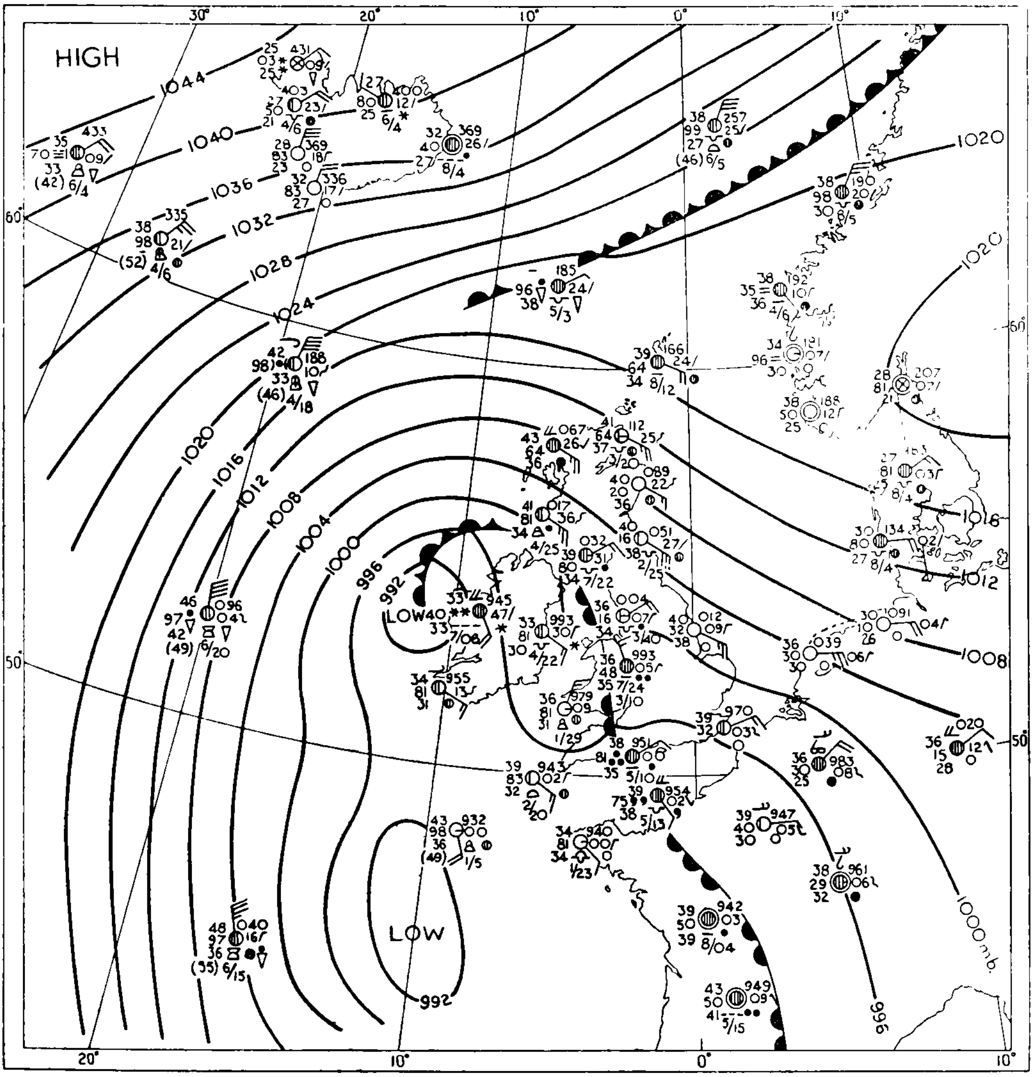

30°
20°
10°
0°
10°
HIGH
1044
1040
1036
1032
1028
1024
1020
1016
1012
1008
1004
1000
996
992
LOW
LOW
992
1020
1020
1016
1012
1008
1000 mb.
996
60°
60
50°
50
20°
10°
0°
10°

FIG. 3—SYNOPTIC CHART, 0000 G.M.T., MARCH 8, 1951

of the Faeroes and the ocean weather ship at 59°N., 19°W.; both these stations had dew points above 32°F. The immediate origin of the cold air lay in the Jan-Mayen–Bear-Island area. An old occlusion ran north-eastwards from just north of the Faeroes, but this was subsequently dropped from the official analysis of the Central Forecasting Office, Dunstable. Twenty-four hours later the drier air had moved south of the Faeroes, but was still to the north-west of southern Norway and north of the ship at 59°N., 19°W. This cold tongue, bulging southward, was due primarily to the very pronounced anticyclone over Greenland (central pressure over 1050 mb.), and was responsible for the formation of a marked trough off south-west Norway in which a polar low formed on March 9. The dew point at the Faeroes, after falling as low as 19°F. at 0900 on the 9th, rose to 32°F. at 1200 and to 36°F. at 1800; dew points in Iceland by this time were down to 16°F., and it was clear that the tongue of cold air, having first protruded southwards over the Faeroes, later moved slightly westwards, causing the observed fall and subsequent rise in dew points at that station. The westward boundary of the tongue at this time lay somewhere to the east of the ship at 59°N., 19°W.

Further southward movement of the cold air was indicated by falling dew points in north-west Scotland behind a belt of snow which moved south-east. By 1800 on the 9th, the dew points at Cape Wrath, Stornoway and Benbecula were down to about 25°F. and snow was falling along a line from Shetland to Kinloss, Dalwhinnie and Tiree. At 0000 on the 10th the boundary lay just north of Blacksod Point, south of Ballykelly, through Kinloss, Wick and Orkney and west of Shetland. Throughout all this time, the dew point at the ocean weather ship at 59°N., 19°W. had remained at 32°F. or above and no movement of drier air over the ship from east to west had occurred, nor in fact ever did occur despite the north-easterly air flow in that area during the entire period. It must therefore be concluded, and the conclusion is verified by subsequent events, that at 0000 on the 10th, the boundary of the colder air, partially indicated above, was completed by a line curving from west of Shetland to south of the Faeroes and thence south and south-eastwards to Blacksod Point. Early in its history, therefore, the tongue of cold air had been converted into a "bubble", cut off from the main reservoir in the Iceland area by the westward movement of air which had spent some little time over the sea between Scotland and Norway.

The subsequent movement of this bubble of relatively colder and drier air, and the subsidence which occurred within it more especially to the south and south-east of the centre of the polar low with which it was associated, explains the fine weather which spread eastwards over south Scotland on March 10. The southern and eastern boundary of the bubble had the characteristics of a cold front, and could be related to the old occlusion lying to the north of the Faeroes on the 8th (Fig. 3).

Subsequent synoptic history.—It may be of interest to record that the bubble, considerably shrunken, was still in evidence on March 12, with fine weather over Northern Ireland and the Western Isles south of Benbecula. It subsequently moved north-eastwards after splitting in two, and then north or north-westwards, and was last in evidence as a solitary observation from Cape Wrath at 1800, March 13, with a dew point of 25°F.

The movement of the polar low (Fig. 2) is also of interest. It was formed on the 9th in the trough off south-west Norway, with the cold tongue lying to the west. It first moved south-south-west as was to be expected from the pressure-tendency field and the thermal pattern. At this time the bubble lay mainly to the west of the low. Later the bubble moved south more quickly than the low, and the two appeared to act as a dumb-bell, the low being swung very sharply west round the northern boundary of the bubble before resuming its mainly south-westward movement. It is quite likely that there is more than coincidence here, although it is impossible to prove which was cause and which effect. It should be noted, however, that once the colder air of the bubble had moved to the south or south-west of the polar low, some slight distortion of the thermal pattern would take place, a westward component being added in the neighbourhood of north Scotland, which would be the stronger, the deeper the bubble. In this case the bubble was limited in depth to below about the 800-mb. level, but may have been deep enough to steer the surface low to the west.

Mr. C. K. M. Douglas writes: "The subsequent motion of the low can be looked at in at least two ways. One could regard it as dominated by the movement of the upper depression steered by the Greenland anticyclone which was pronounced at 500 mb. Alternatively one could lay the emphasis on the lower current which was advecting cold air to the south-west and producing a moving area of 'relative divergence' on the thickness pattern with falling sea-level pressure under it. These aspects are not incompatible but the complete problem is not yet understood."

Conclusion.—The unexpectedly fine weather which spread east over south Scotland on March 10, 1951, can be ascribed to the formation and subsequent life history of a bubble of colder and drier air which became detached from a reservoir in the Iceland region. Unlike a cold pool, which involves considerable thickness and may not be directly in evidence on the surface at all, the bubble may be thought of as a shallow dome.

Isolated patches of drier air are fairly frequent, but are very rarely so pronounced as on this occasion. Even the most homogeneous air mass contains minor irregularities due, for example, to variations of the sea track or of the surface topography over which the air mass has passed, but the "seclusion" of such a large bubble in the manner here described must be very unusual. So far as is known a description of the phenomenon has not previously been published.

Acknowledgement.—The author is indebted to Mr. C. K. M. Douglas for helpful comments on the situation and to Mr. S. E. Virgo for discussions.

METEOROLOGICAL OFFICE DISCUSSION

Evaporation as a factor in hydrology

The first discussion of the 1951–52 series, held at 11 Carlton House Terrace, on October 8, 1951, dealt with evaporation as a factor in hydrology. It was opened by Mr. A. Bleasdale with a statement based on the following papers.

BENTON, G. S., BLACKBURN, R. T., and SNEAD, V. O.; The role of the atmosphere in the hydrologic cycle. *Trans. Amer. geophys. Un., Washington D.C.*, **31**, 1950, p. 61.

GLASSPOOLE, J.; Rainfall, run-off and evaporation. *Wat. & Wat. Engrs, London*, **55**, 1951, p. 16.

PENMAN, H. L.; Evaporation over the British Isles. *Quart. J. R. met. Soc., London*, **76**, 1950, p. 372.

Whilst dissimilar in their approaches, the three papers have the common feature of dealing with broad general effects in which evaporation plays a part, and not with the details of the physical process. They therefore lend themselves to discussion of various aspects of the hydrological cycle through which the material of the different authors may be brought together.

The first paper sets out to disprove a theory which gained some acceptance in the past, and even in recent years, that a great part of the water precipitated over a continent is derived from moisture evaporated over that continent. A consequence of this theory is that modification of land use in such a way as to alter the evapo-transpiration over an area could affect precipitation over that area or nearby areas. Hence it has been seriously suggested that a chain reaction—precipitation–evaporation–precipitation—can be encouraged, and that this will then persist until the loss due to run-off, which may be relatively small, depletes the area of its moisture.

Quantitative evidence for or against this theory was lacking until recent times, and the present paper includes an analysis of upper air data, bringing out the separate roles of maritime and continental air masses, which has been made possible only by the developments of the last 10–15 years.

The method employed is to set up simple water-balance equations for the Mississippi basin, taken as a convenient example of a continental area, and to estimate the relative magnitudes of the component terms. The treatment given to the different components is not at all uniform, and the analysis is open to criticism on these grounds, and also because there is no final check on the balance of the equations. The basis of the estimates, starting from mean annual values of (*a*) general rainfall over the basin, (*b*) distribution of evapo-transpiration, and (*c*) total run-off, may be summarized as follows:—

	Based on data from:-
(i) Separation of rainfall amounts from maritime and continental air masses respectively	1 station for 1 year (1946)
(ii) Separation of evapo-transpiration amounts into maritime and continental air masses respectively	5 stations for 5 years (1942–46)
(iii) Transport of water vapour into the basin by maritime and continental air masses respectively	14 radio-sonde stations for 3 years (1946–48)
(iv) Transfer of water vapour from maritime to continental air masses	estimated
(v) Transport of water vapour from the basin by maritime and continental air masses respectively	derived from (i), (ii), (iii) and (iv)

It is argued that it is not feasible to make independent estimates under item (v), and the absence of such estimates means that there is no check on items (i)–(iv). This is unfortunate, particularly in view of the rather mixed sets of years which are used to estimate supposedly comparable averages for the different items.

Nevertheless the general conclusion is probably beyond doubt: that the quantities of water vapour transported over the basin (items (iii) and (v)) are overwhelmingly larger than any of the other items. Only about 20 per cent. of this water is ever precipitated over the basin, and therefore it may be calculated that not more than 12–14 per cent. of the precipitation can be land-derived, the remainder being oceanic in origin. An increase in evapo-transpiration due to changes in land use can thus have very little effect on precipitation in surrounding areas, since the amount of precipitation must depend primarily on such factors as the intensity of the hemispheric circulation.

Generally speaking, precipitation is not and cannot be a chain reaction, but the authors conclude on a note of caution: the amount of 12–14 per cent. which represents land-derived precipitation applies to the Mississippi basin as a whole. Locally (and presumably in some other parts of the world) it could be as high as 20–30 per cent. So that the effect may be important for some areas. The authors still feel that "owing to the exteme mobility of the atmosphere the land sources for precipitation in one region are bound to be hundreds or even thousands of miles away from that region. Increasing or decreasing precipitation even slightly by local regulation of land use is therefore out of the question."

The opener thought, however, that just as the general figure of 12–14 per cent. must be looked at with the possibility of local variations in mind so also the possibility of variations in individual years, and more especially in individual seasons, must be considered. In place of the attempt to estimate average conditions from small and mixed sets of years, it might have been possible to take the summer and winter half-years separately in, say, three individual years, in order to estimate seasonal and yearly fluctuations in the quantities involved in the water-balance equations. It is not inconceivable that the percentage of precipitation which is land-derived will be highest when it is most important (economically) that it should be so, i.e. in individual years or seasons when the hemispheric circulation is relatively weak and precipitation generally is deficient.

Glasspoole considers the various components of the hydrological cycle and stresses the need to consider them in conjunction. The state of affairs in this country has not hitherto been very satisfactory in that various bodies (which are enumerated) have specialized in different branches of hydrology, but central co-ordination has been lacking.

In the section dealing with evaporation the factors affecting its variation are discussed to show that in this country the most important variation is the seasonal difference between summer and winter months. Variations from year to year, and even from one part of the country to another, are relatively small. In so far as this may also be true for the Mississippi basin (and most areas having well marked seasonal cycles of temperature, duration of sunshine, vegetable growth, etc.), the suggestion made with regard to the American paper is supported.

Sources of quantitative information are discussed with a review of their limitations, and with indications of the degrees of agreement obtained by the use of different techniques of measurement and estimation. Some of the important quantitative results may be summarized as follows:—

Seasonal variation in the British Isles.—About 85 per cent. of the annual evaporation occurs in the summer half-year from April to September, and nearly 95 per cent. in the eight months March to October.

Variation over the British Isles.—Annual evaporation amounts to about 13 to 14 in. in the north of Scotland and is about 50 per cent. more in southern England. There is a similar but smaller increase, probably from north-east to south-west, over Ireland.

Example of relative loss due to evaporation.—For the catchment area of the Thames above Teddington weir, the loss is about two-thirds of the annual rainfall over the area. This compares with just over three-quarters for the Mississippi basin as given in the first paper.

The general trend of Glasspoole's treatment is that, from the point of view of the practical hydrologist, evaporation represents a very important loss from the water resources of this country. The reduction of this loss by the use of covered reservoirs is impracticable on any large scale; therefore, since the loss is mainly confined to the summer half-year, it may be more profitable to approach the problem by considering the timing of the use of surface water and underground supplies. If greater use could be made of the abundant surface supplies in winter, there would be conservation of naturally stored underground water which could be drawn on more extensively in summer when the surface supplies become depleted.

Penman's paper is an application of an equation previously derived[1] to estimate mean annual evaporation over the whole of the British Isles. The method adopted is a combination of the two classical approaches to evaporation studies, the energy-balance approach and the hydrodynamic approach. The latter involves consideration of the theories of turbulent transport developed by Sutton, Pasquill and others, and Pasquill[2] has made a fundamental criticism of the method, which is undoubtedly important. The basis of the criticism is twofold: first, that the method assumes the identity of the eddy diffusivities of heat and momentum, an assumption which Pasquill shows to be invalid in unstable conditions*; secondly, that the hydrodynamic relation used by Penman is empirical and valid only in very limited circumstances which do not occur very often in nature.

In the present paper, Penman recognizes the criticism and suggests that, if it is accepted, his estimates of annual evaporation may be reckoned as about 5 per cent. too high. It seems reasonable to adopt the attitude that, whilst Pasquill's criticism should be followed up in the interests of clearer theoretical understanding, Penman's estimates may be accepted as substantially correct, at least until the appearance of similar estimates which are demonstrably better. Their value has already been established in practical applications.

The meteorological data required are mean values, for the period under consideration, of duration of bright sunshine, air temperature, vapour pressure and wind speed. The period may be a month or a year to obtain reasonably accurate results. An intermediate step in obtaining natural evaporation, or evapo-transpiration, is to calculate the hypothetical evaporation that would take place from an extended sheet of open water exposed to the given conditions. A direct check has been possible in one case (Abberton reservoir near Colchester) and mean monthly values over 8 years for July, August and September showed the estimates to agree with the actual observations within about 6 per cent.

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*Pasquill's conclusion has again been questioned and the matter is still controversial.

Penman's final map gives mean annual values for 102 stations distributed over the British Isles. There is good general agreement with the values of mean rainfall minus mean run-off for 41 catchment areas covering a great part of the country, though the precise isopleths for the distribution of mean annual evaporation cannot be drawn with confidence.

Penman's claim regarding the accuracy of the estimates (5–10 per cent. for individual years and 15–20 per cent. for individual months, quoted from a later paper[3]) is probably well founded, and in this connexion it is relevant to consider the accuracy which may be attained in other hydrological measurements. In the most favourable cases the general rainfall over an area and also run-off may be assessed with much greater precision (e.g. probably to within 3 per cent. for general rainfall over the Thames Valley), but there are unfavourable cases (e.g. the general rainfall of mountainous areas with a sparse network of stations) for which great accuracy is not yet attainable. It is probable that the estimation of evaporation is at present more or less on a level, with regard to accuracy, with the measurement of other hydrological quantities, though the factors which affect accuracy will operate very irregularly, so that the quantity which is most accurately assessed will not always be the same. With the improvements that can be expected within the next few years in the hydrological field (arising largely from the River Boards Act of 1948 and allied developments), it is likely that Penman's method will require some refinement, and it is in this respect that the stimulus of Pasquill's theoretical criticism should prove its value.

The paper concludes with reference to practical applications which illustrate an earlier statement in the introduction, that natural evaporation "can be the dominant factor in successful agriculture and in practical hydrology". Subsequent work, in particular controlled irrigation experiments continuing the early ones referred to, has amply demonstrated the significance of this view.

When the attempt is made to bring out the relationship between the present (or similar) papers by reference to the hydrological cycle, the form of diagram currently in favour with such authorities as Linsley, Kohler and Paulhus[4] does not lend itself readily to the purpose. Whilst having the virtue of being more or less complete, this form does not bring out very clearly the outstanding features of some important sectors of the cycle. A form of the diagram may be prepared (Fig. 1) which, whilst not intended to be absolutely complete, is based on a logical scheme giving prominence to the basic components in their relationships both to each other and to the relevant fields of study.

In this diagram the upper half represents the vapour phase and the lower half the liquid or solid phase; the left-hand half covers sea areas and the right-hand half the land. The diagram in this form could be elaborated for any specific purpose, and, as an example and as a concession to completeness though not of special interest at present, the tidal ebb and flow in river estuaries has been represented. This sub-cycle C shows the normal rhythmic interference with the continuous process of run-off; but there is also a separate branch g to indicate that, when there is a tidal contribution to flooding, a part of the tidal water becomes involved with surface water and soil moisture.

Considering the diagram in quadrants, the processes making up the lower left-hand quadrant received a bare mention in the first paper, but were otherwise not dealt with; they are in the field of marine meteorology. The American authors cover the remainder of the cycle, but their quantitative work is concentrated mainly in the field represented by the upper right-hand quadrant. It is their contention that the sub-cycle A, which takes place wholly within the atmosphere and consists solely of the vapour phase, involves such enormous quantities of water vapour and is so vigorous that the branch e, representing evapo-transpiration over land, is very largely drawn into it. This branch, therefore, can make but a small contribution to precipitation over land, and the uppermost arc f of the sub-cycle B over land can be virtually eliminated. The latter sub-cycle cannot have a completely independent existence (described as a chain reaction), but in the main exists merely as a loop from the atmospheric sub-cycle A which derives its dominant independent existence from the vigour of the general circulation and the quantities of water vapour involved therein.

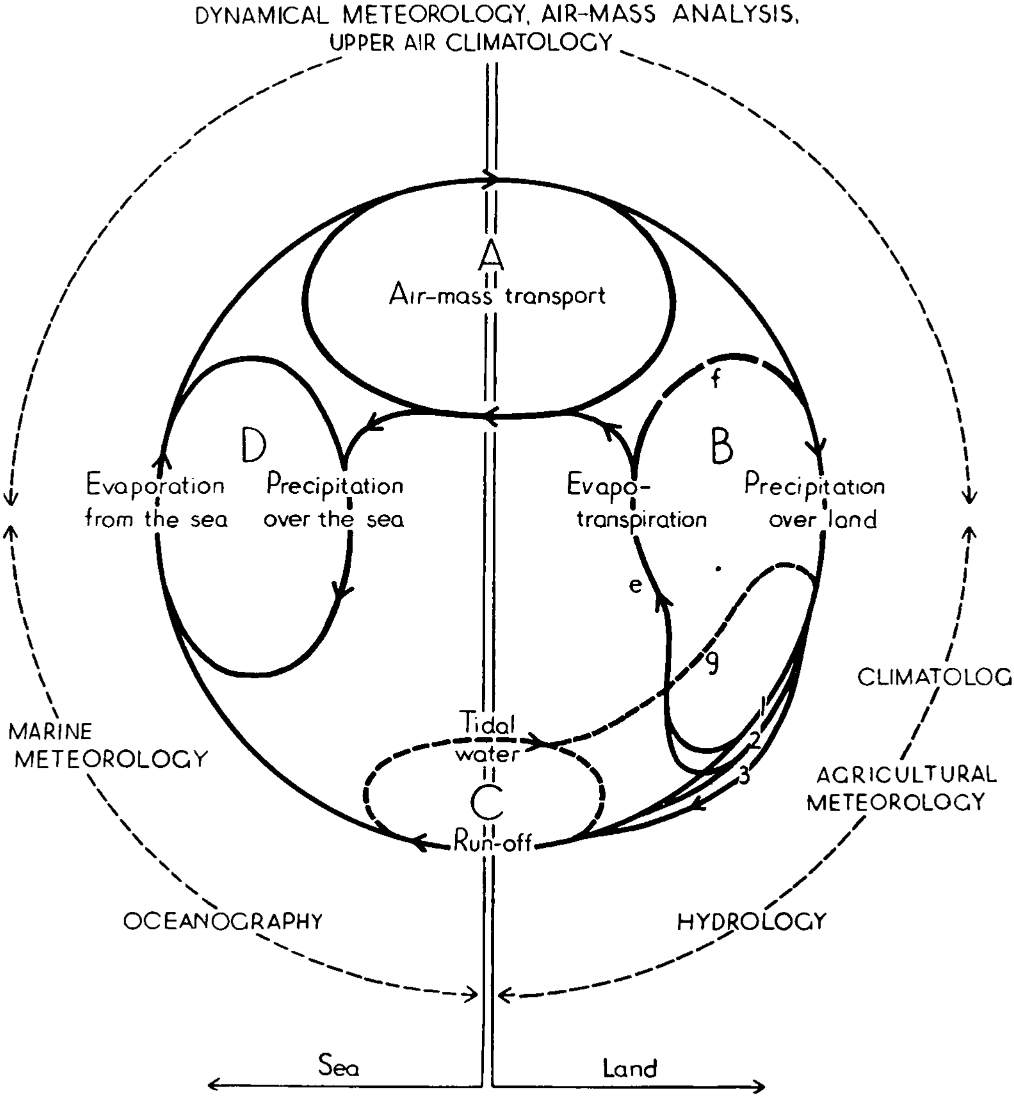
DYNAMICAL METEOROLOGY, AIR-MASS ANALYSIS, UPPER AIR CLIMATOLOGY
A
Air-mass transport
f
D
B
Evaporation from the sea
Precipitation over the sea
Evapo-transpiration
Precipitation over land
e
g
1
2
3
Tidal water
C
Run-off
MARINE METEOROLOGY
OCEANOGRAPHY
CLIMATOLOGY
AGRICULTURAL METEOROLOGY
HYDROLOGY
Sea
Land

FIG. I—HYDROLOGICAL CYCLE

1. Surface water, snow, ice 2. Soil moisture 3. Ground water

Though some doubts have been suggested above about the universal validity of this argument, it must for obvious reasons hold good for the British Isles. The fact of its implicit acceptance appears in the papers by Glasspoole and Penman who deal only with processes represented in the lower right-hand quadrant of the diagram. The out-going evapo-transpiration branch has no direct connexion, outside the quadrant, with the incoming precipitation branch; it represents an inevitable loss which can be modified in various ways in its incidence but only in a small degree in its total quantitative effect. This quadrant (with sufficient elaboration) covers the field of study of hydrology proper, at least in the practical sense, with the first paper contributing a border-line subject, of only theoretical interest in this country, from other fields.

Dr. Stagg, in introducing the opener, had pointed out that, though the physics of evaporation had been dealt with in Meteorological Office Discussions on two occasions, the treatment of evaporation in the hydrological setting was a new departure. This was a reflection of the increasing interest being taken in hydrology within the Office. Inviting contributions to the discussion, he suggested that the question of the relative accuracy of hydrological measurements should not be permitted to lead too far towards detailed consideration of physical principles, but should be kept in the wide general field already indicated. He thought that there was a need to discuss also the importance of the role of underground water in the hydrological cycle.

Cdr. Frankcom dealt with the importance of the oceans to hydrologists and with the relative neglect of the processes represented by the lower left-hand quadrant of the diagram of the hydrological cycle. This neglect could be explained by the great difficulty of making reliable measurements of rainfall and evaporation from ships. Attempts were being made to overcome this, but it had also been found difficult in the past to relate data from moving ships with data from adjacent land stations.

Mr. Gordon referred to the recent Maritime Conference at Genoa at which the hydrological balance of the Mediterranean and the Baltic Seas had been discussed. It had been deduced that for the former evaporation was of the order of four times the rainfall, and for the latter the two approximately balanced.

Mr. Houghton discussed the measurement from ocean weather ships of the temperature gradient of the upper layers of the sea on quiet afternoons. He showed graphs of the two forms of curve obtained with air temperature less than sea temperature (unstable lapse rate in the lower layers of the air) or greater (stable lapse rate). The diurnal variation of temperature was closely linked with the heat loss due to evaporation, and the data showed promise of yielding an estimate of evaporation from the sea.

Mr. Veryard asked for information about run-off and its measurement, and about the accuracy of measurements of run-off and of rainfall.

Dr. Glasspoole pointed out that attention had been paid to the accuracy of run-off data for a long time, details of published papers being given in the Report for 1950 of the Inland Water Survey Committee[5]. Similarly much thought had been given to maintaining the accuracy of rainfall records by inspecting rainfall stations, estimating any errors quantitatively and putting them right, and by examining the fit of the records on maps. The accuracy of rainfall and run-off values could best be judged by detailed comparison of the data for the same area, and with evaporation values as determined by Penman's method.

Dr. Penman, Rothamsted Experimental Station, replying to Dr. Stagg, said that the variations in underground water storage could be virtually eliminated by taking very long-term averages, but that over a period of a few months or only one year it could be shown that the variation in storage was important. Thus the basis of his method of dealing with the water balance of the Stour[6] and the Thames[3] was to treat storage as the unknown quantity dependent on other terms in the water-balance equation, which could be measured or estimated. He stressed the need for more well records, to correlate with calculated variations in storage. In commenting on the accuracy of data he said that this could be very varied, particularly for run-off.

Dr. Stagg asked whether there is any check on the accuracy of run-off records comparable with the systematic inspection and checking of rain-gauges and rainfall data carried out by the British Rainfall Organization of the Meteorological Office.

Mr. Allard, Inland Water Survey, Ministry of Local Government and Planning, explained that the Inland Water Survey collects and examines run-off data and visits the sites of river-gauging stations whenever possible, but that the final check is given by the degree of agreement with rainfall and evaporation data. Whilst there were bad cases he was of the opinion that published data[7] were accurate within 5–10 per cent.

Dr. Buchan, Geological Survey, Department of Scientific and Industrial Research, described the task of the Geological Survey as the estimation of undeveloped ground water resources, and mentioned the role of observation wells in this work. He felt that we could expect progress in several branches of hydrological work within a few years. Taking the Lea Valley as an example he explained how underground storage in one place (in this case under impermeable clay) could depend on percolation elsewhere. From data of the abstraction of water from below London, evaporation in the chalk area of the Lea Valley could be deduced.

Capt. McClean discussed the high degrees of accuracy which could be obtained in run-off measurements where the river-gauging station had been thoroughly investigated with flow-meter measurements, or where properly constructed weirs or flumes were in use. Where volumetric estimates depended only on observations of river stage, accuracy over the whole range was rarely to be expected. Similarly there was a need for greater accuracy in rainfall assessment in some areas, particularly mountainous areas.

Mr. Gold suggested the need for a new word to replace "evapo-transpiration" and to mean "the quantity of water removed by the atmosphere"; this was the quantity of interest to hydrologists, and in the processes of evaporation, transpiration, dew formation, etc., it would be less than the total quantity of water evaporated and transpired. He considered long-term storage effects to be small in comparison with rainfall and run-off, and spoke of recent work[8] on the lag in run-off as compared with rainfall in which he had shown that for the Thames Valley the rainfall of the preceding three quarters had a perceptible effect on current run-off, whilst the effect of the rainfall in earlier quarters was negligible. He had also shown that when monthly amounts of rainfall minus run-off are plotted against rainfall, the points lie very close to a straight line, showing that the loss due to evaporation increases regularly with rainfall, at least over a large range, not only in summer but even in winter, though the regularity is somewhat reduced.

Mr. Ward, Building Research Station, Department of Scientific and Industrial Research, spoke of the difficulty of allowing for the changes in percolation and underground storage due to progressive urbanization during a period taken to assess averages. (Dr. Buchan thought that the effect would not necessarily be great.) He thought that town run-off might often be passed for storage into the chalk instead of being run wastefully into the rivers.

Dr. Stagg closed the discussion, after a few small outstanding points had been cleared up, with a reference to the appreciation by the Meteorological Office of the interesting contributions from outside visitors.

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HONOURS AND AWARDS

The Council of the Institute of Navigation have awarded the Bronze Medal for the best paper to be published in any year in the Institute's Journal to Mr. C. S. Durst and Mr. N. E. Davis for their paper "Jet streams and their importance to air navigation" which was published in Volume 2*. The Council have awarded a Fellowship of the Institute to Cdr. C. E. N. Frankcom, R.N.R.

LETTER TO THE EDITOR

Halo phenomena at Prestwick, August 31, 1951

The phenomena were first observed at approximately 1115 G.M.T. by the duty observer, who drew attention to a patch of what seemed to be at first iridescent cloud above the sun, but on closer inspection was seen to be a very marked upper tangent arc associated with a weak 22° halo. The arc of contact was brightly coloured with orange, yellow and green clearly defined. While the phenomena lasted the total amount of cloud was never more than 6 oktas and was mainly thin cirrostratus with patches of altocumulus.

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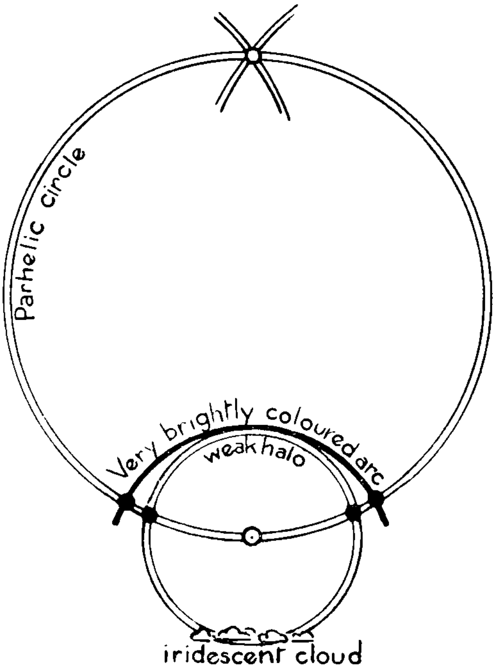
* *J. Inst. Nav., London*, **2**, 1949, p. 210.

A few minutes after first noticing the halo a well formed parhelic circle was seen, and, with the arc of contact, remained the salient feature of the phenomena. Four well defined mock suns were observed at the points of intersection of the halo, arc of contact and parhelic circle (see diagram).



The most interesting occurrence, however, was observed approximately 45 min. after the phenomena were first noticed when two very weak partial curves were seen to be producing a weak mock sun at their point of intersection on the parhelic circle immediately opposite the sun.

The phenomena gradually disappeared with the dispersal of the upper cloud, having lasted for approximately 1hr. 50min.

The elevation of the sun at noon was 42°.

R. A. HAMILTON
J. T. RONXIN
A. P. PARRY

September 6, 1951

[The interesting features are:—

(i) It is unusual for the tangent arc to the 22° halo to be brightly coloured.

(ii) The parhelia observed at the points of cutting of the tangent arc and parhelic circle appear to be the true parhelia which, for a solar elevation of 42°, would be situated very near the points given.

(iii) The parhelia described as situated where the halo met the parhelic circle appear to be due to an additive illumination effect sometimes noticed where two arcs of illumination cut.

(iv) The anthelic arcs are rather rare. Humphreys* states that the anthelion itself is rare. — Ed. *M.M.*]

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*HUMPHREYS, W. J.; Physics of the air. New York and London, 3rd edn, 1940, p. 538.

NOTES AND NEWS

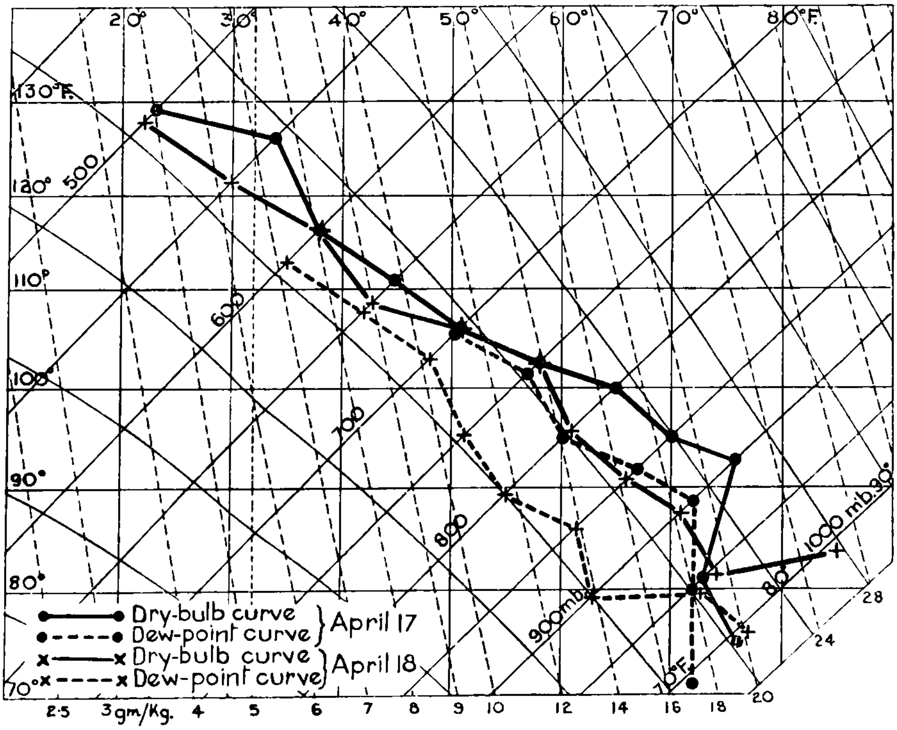
Clear-air turbulence

On April 17, 1951 at 2050 G.M.T. a Dakota, which had just left Changi (Singapore) for Saigon, was climbing slowly and smoothly 18 miles north of Changi when it suddenly encountered violent turbulence in clear air over south Malaya.

The aircraft fell from 4,800 ft. to 3,000 ft. (according to altimeter) in five seconds, while indicated airspeed of 110 kt. changed to between 160 and 180 kt. The crew of three were pinned to the roof for a short time but not "blacked out". A sextant inside its case was badly dented and the case smashed. Stoppers on all the large vacuum flasks were ejected and loose equipment scattered.

The incident took place over flat mangrove swamp and jungle nine miles from the South China Sea but only four miles from the tidal waters of the Johore river estuary. There was no moon and it was about two hours before dawn twilight (0420 April 18, Malayan Time).

The intertropical front was 300 miles to the north and the air up to 10,000 ft. had its origin in a southern subtropical anticyclone near Australia. This air had dried out and cooled considerably during the previous day as the tephigram shows, but cumulus formation over and near a sea surface of temperature 81°F. was possible. Records for nearby stations show that showers died out in the area the previous evening and did not reappear the following day, cumulus amounts remaining below 3 oktas throughout the night and the following day. Distant lightning was observed, however, to the north, west and south near the time of the occurrence by the crew of the aircraft and by meteorological



TEPHIGRAM OF SPITFIRE ASCENTS AT SINGAPORE, 0130 G.M.T., APRIL 17, 1951 AND 0200 G.M.T., APRIL 18, 1951 observers on Singapore Island, but no one observed low cloud near to their own position. Barographs at nearby stations revealed no unusual changes of pressure at the time. The winds over the area as observed by pilot balloon at Changi at 2030 G.M.T. were less than 10 kt. between south and west up to 7,000 ft.

If the crew's observations were correct, there must have been an acceleration of at least 9*g* at some stage. For, assuming no vertical velocity at the beginning and end of the five seconds during which the aircraft fell 1,800 ft., and a steady downward acceleration *f* followed by a steady upward acceleration *f*, we have:—

$$900 = \tfrac{1}{2} f \left(\tfrac{5}{2}\right)^2$$

$$\text{or} \quad f = 9 \times 32 = 9g$$

and for any other type of motion under these conditions, a greater acceleration is involved. Thus it is quite clear that the observations are not accurate in spite of the fact that both pilot and navigator are agreed, since a crew normally "black out" under about 5*g*. The erroneous readings may have been height, as recorded by altimeter, or time. With regard to time it would be unusual for a crew to underestimate the time of a nerve-shattering experience, the tendency being to overestimate. The altimeter readings, based as they are on pressure, are suspect, particularly as the expulsion of stoppers from the vacuum flasks indicates large fluctuations of pressure.

However, it is certain than an acceleration of more than 1*g* downwards was experienced since we have the evidence of the crew pinned to the roof and the smashed sextant case. This in itself is sufficiently remarkable if the incident was actually in clear air. On this latter point the crew were quite definite that they were not in cloud, while observers at Changi, 18 miles away, confirm that although there was no moon it was light enough to see cloud.

The most likely explanation would appear to be an eddy with a horizontal axis, but while this has been observed in cumulonimbus, it seems far less likely in clear air, especially with such light winds in the area.

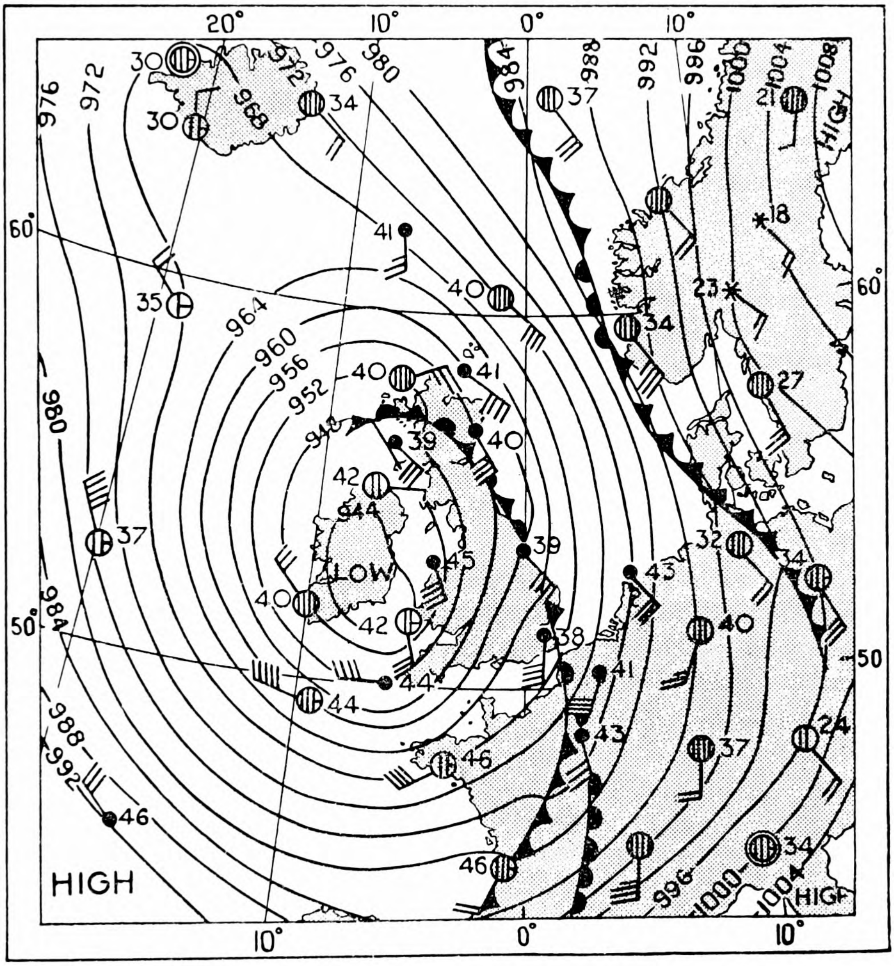
P. E. PHILLIPS

Low pressure recorded on February 4, 1951

On January 31, 1951, a depression developed on a very pronounced front near the southern coast of the United States, in the Gulf of Mexico. At 0600 G.M.T. on February 2 it was centred near the north-east corner of the United States, at 46°N., 71°W., with central pressure 996 mb., and 24 hours later at 53°N., 43°W. with pressure about 985 mb. After another 24 hours, at 0600 on the 4th, it was close to west Ireland with a central pressure about 944 mb. It was then occluded up to 300 miles from its centre and its speed and rate of deepening were rapidly decreasing. Throughout its movement from the Gulf of Mexico to Ireland it was in a very strong thermal field which enabled it to combine rapid movement with sustained deepening which became rapid on the 3rd. The presence of a large warm anticyclone to the west-south-west of the Azores, with central pressure over 1040 mb. on the 3rd, favoured the maintenance of a large warm sector. During the period of rapid deepening on the 3rd–4th this anticyclone decreased slightly in intensity, as also did the Russian anticyclone.

By 1200 on the 4th the depression appears to have temporarily developed two centres, one near Malin Head in Northern Ireland and the other near Cork, with pressure of about 944 and 942 mb. respectively. Subsequently it filled up slowly whilst drifting north-eastwards, turning north-north-west later.

The depression was remarkable for the low pressure to which it gave rise over the whole of the British Isles. It was not exceptional in other respects although there were fresh to strong gales around our coasts. Rainfall amounts were not large. Letters were received in the Meteorological Office from members of the general public in all parts of England and Wales, and also in Eire, reporting the exceptionally low pressure and asking for details as to its cause.


20°
10°
0°
10°
60°
50°
976
972
968
964
960
956
952
948
944
976
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996
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LOW
HIGH
HIGH
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10°
0°
10°
50
60°

SYNOPTIC CHART FOR 1800 G.M.T., FEBRUARY 4, 1951

The lowest pressure seems to have occurred at Midleton, Co. Cork, where the mean-sea-level value was 942·3 mb. at 1500 on the 4th, a record for February for the British Isles. Other stations reporting record low pressure for the month were Oxford (956·2 mb. at 0000 on the 5th), Southport (950·4 mb. at 2100 on the 4th) and Kew Observatory (961·2 mb. at 2200 on the 4th).

For comparison the lowest pressure ever recorded at Kew, where records began in 1869, was 959·3 mb., reduced to mean sea level, on December 9, 1886. The record for the British Isles is 925·5 mb., recorded at Ochtertyre, near Crieff, Perthshire, on January 26, 1884, and the world record 887 mb. in the Pacific Ocean on August 18, 1927.

Some depressions which attain exceptional depth have a more complex structure than this one, with more deepening after the first occlusion. The fall of pressure at Cork of 70 mb. in 54 hours and of 62 mb. in 30 hours was probably as unusual as the low minimum itself. Very low pressures over or near the British Isles more often follow a low general pressure level in the area.

H. C. SHELLARD
C. K. M. DOUGLAS

Radar and bright-band cloud echoes in Southern Rhodesia

The Rhodesia Meteorological Service has a Naval Type 277 radar in use at Salisbury, Southern Rhodesia. The aerial unit is mounted on a 40-ft. steel tower, and transmitter, receiver, displays and associated equipment are housed in a building constructed around the legs of the tower.

Installation began in September 1950 and, after a number of difficulties had been overcome, the set was in proper working order by the middle of February 1951.

The radar is being used for experimental and research purposes in the directions of storm detection and cloud study. Experiments are also being carried out with a view to using the set for upper wind measurement.

During the 2½ months of rainy season in which the set has been in use, very interesting results have been obtained. The most striking observations are those of bright-band echoes. This type of echo, obtained by directing the radar beam vertically upwards at a precipitating cloud, has so far been observed on two occasions.

On the first occasion a thundery shower occurred at the station, giving a steady rate of rainfall for 15 min. and thereafter a steady fall for 75 min. at a rate of about one-tenth the initial rate. During the first period, the vertical radar beam showed cloud and rain echo extending to more than 20,000 ft. above ground, i.e. 25,000 ft. above sea level; this echo was unchanging and had no special characteristics. During the second period of lower rate of rainfall, a bright band of echo was observed between 9,000 and 10,000 ft. above ground. This band of echo was 3–5 times as intense as the remainder of the echo above and below; it was observed for about 45 min. while no noticeable change took place in height, intensity or thickness of the band.

On another occasion when a line-squall was known to be approaching Salisbury, the movement of the instability volume was recorded by photographing the associated cloud echoes at suitable intervals. A few minutes after the squall had passed through Salisbury, light rain began and the vertical radar beam gave extremely interesting bright-band echoes. There were frequent intervals of several minutes together when no cloud echo was apparent. Quite suddenly a band of echo appeared and rapidly intensified; sometimes the band remained in position for perhaps a minute then faded out, sometimes it descended fairly rapidly. Several times a band formed at 9,000 ft. and about half a minute later a second band formed at 15,000 ft.; the latter, after remaining in position for about half a minute, descended to merge with the lower band. At one time a band appeared at 12,000 ft., paused for a few moments then descended; a second band formed at 12,000 ft. and both lowered, while a third band appeared at 12,000 ft. The 3 bands merged to form a single band between

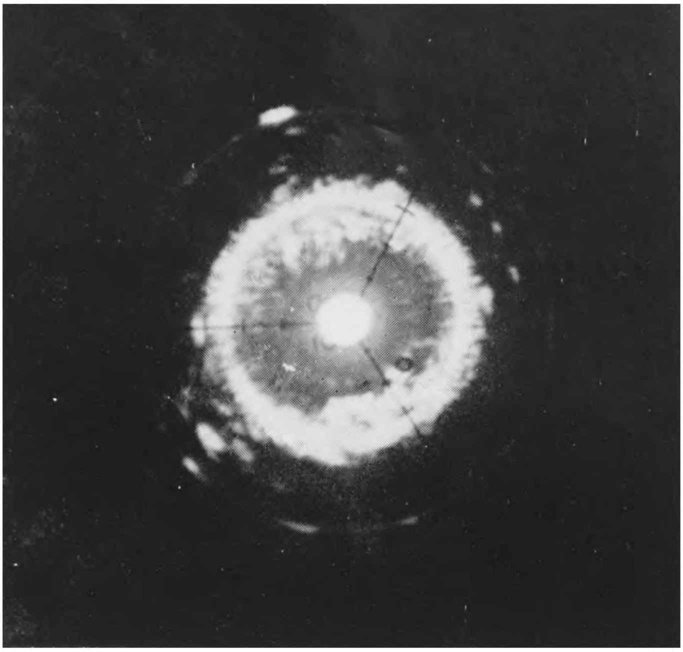


FIG. 1—STRONG BAND ECHO AT 9,000 FT.
Time: 2236

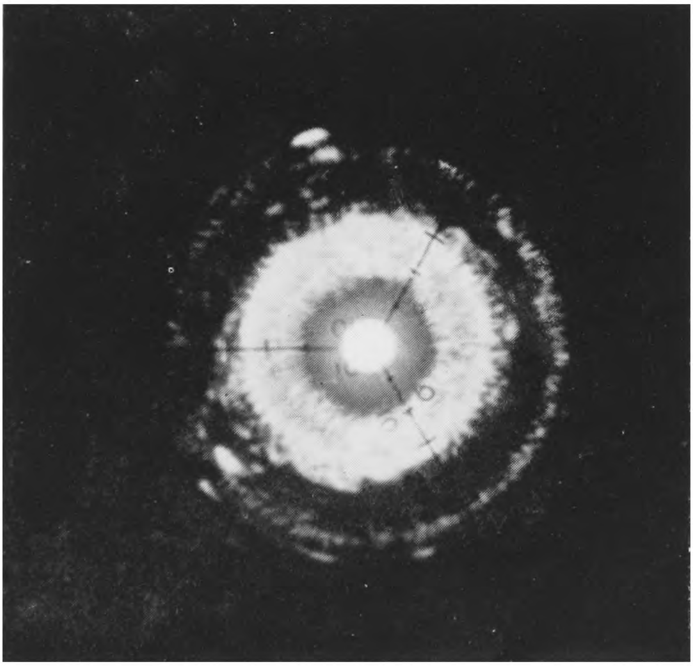


FIG. 2—VERY BRIGHT BAND ECHO AT 9,000 FT. WITH ECHO EXTENDING DOWN TO ABOUT 4,500 FT.
Time: 2238

BRIGHT-BAND CLOUD ECHOES OBSERVED BY RADAR AT SALISBURY, SOUTHERN RHODESIA

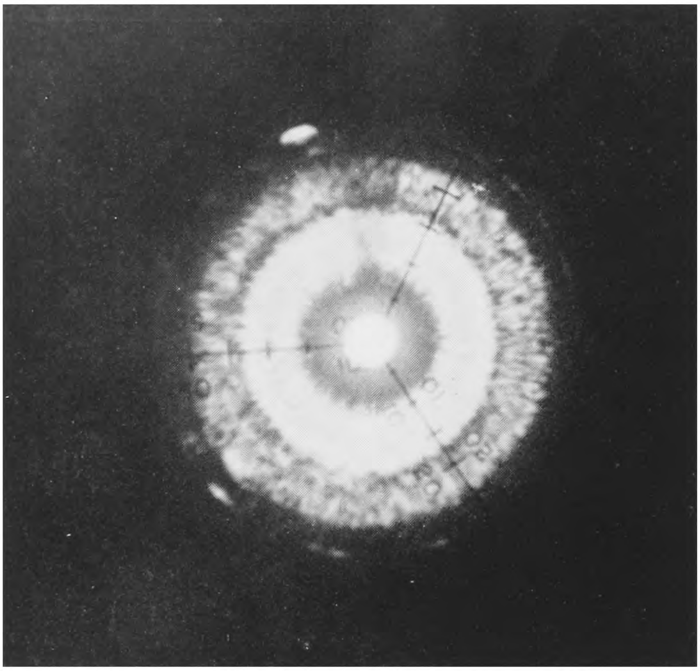
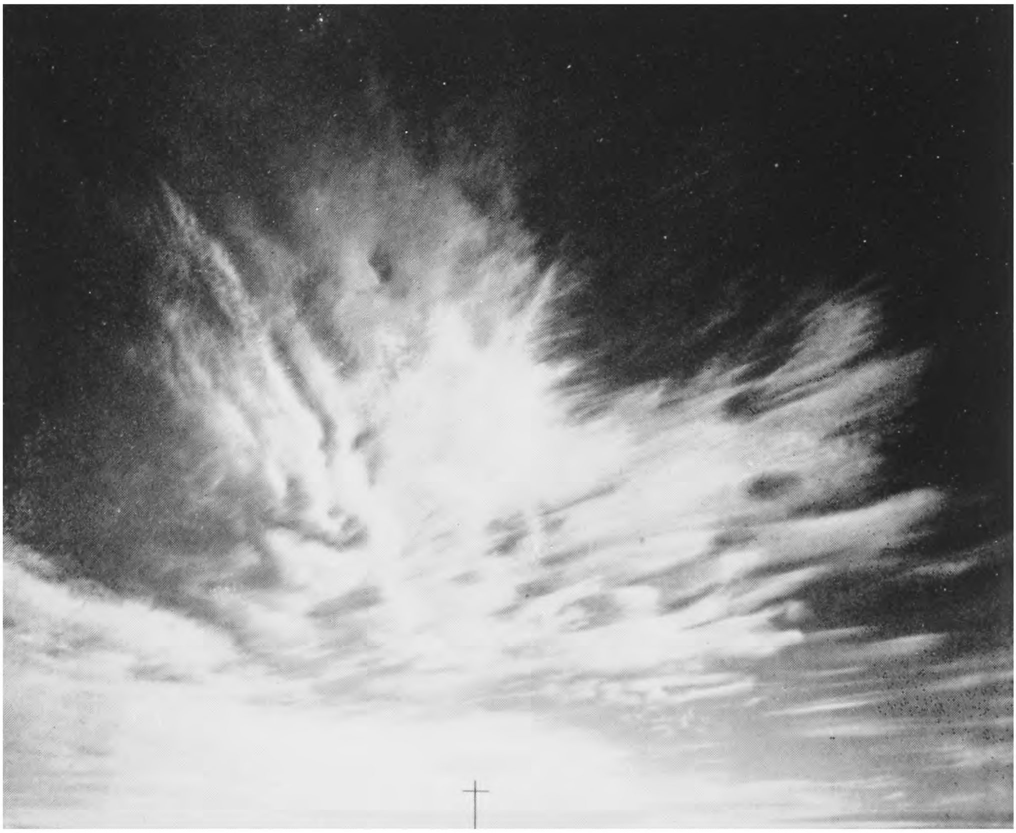


FIG. 3—TWO LOWER BANDS, ONE AT 8,500 FT., ANOTHER AT 6,000 FT., Time: 2239
BRIGHT-BAND CLOUD ECHOES OBSERVED BY RADAR AT SALISBURY, SOUTHERN RHODESIA



Photograph by R.A.F.

CIRRUS AND CIRROSTRATUS IN ADVANCE OF A WARM FRONT
This photograph was taken at a height of 10,000 ft. in 51°N. 16°W. at 1400 G.M.T., January 4, 1949.

7,500 and 12,000 ft. This complete band lowered, narrowed and finally disappeared at about 3,500 ft. Later a single band appeared between 6,000 and 15,000 ft., persisted for about half a minute, then rapidly split up into one band at 15,000 ft. and two merging together at 7,000–8,000 ft.; all the bands descended and faded out.

The photographs facing pp. 364 and 365 illustrate the general appearance of the echo bands as seen on the P.P.I. The bands appear as bright rings whose radius gives the height of the cloud layer from which the echo is obtained. Fig. 1 shows a strong band echo at 9,000 ft. Fig. 2, taken 2 min. later, has a very bright echo band at 9,000 ft. with echo extending down to about 4,500 ft. and an upper descending band at 14,000 ft. Fig. 3, taken 1 min. later, shows two lower bands—one at 8,500 ft. and one at 6,000 ft.; these bands were beginning to separate out in the previous picture; the upper band has descended and widened so that echo extends all the way from 4,500 to 13,000 ft.

V. G. MILES

Very high cloud layer, August 10, 1951

A pilot who flew at about 45,000 ft. from the London area to Lancashire and back between 1230 and 1330 on August 10 telephoned to the Meteorological Office to state that he had observed a thin cloud layer situated at 47,000 ft. The information was considered of such interest that he was asked to send a written report. This he very kindly did and his report is published below with a note on the synoptic situation.

Pilot's report.—On August 10, between 1230 and 1330, I flew from the London area to Lancashire and back at an altitude of 45,000 ft.

At about 30,000 ft., during the climb, it first became apparent that a layer of thin tenuous high cloud existed. At the cruising height of 45,000 ft. this layer was still above the aircraft, giving 8 oktas cover over the area flown but apparently diminishing towards the east.

When approximately over Preston, altitude was increased to check the vertical extent of the cloud and the bottom and top were found to be 46,500 ft. and 47,500 ft. respectively. These figures are only approximate due to the difficulty in identifying the points of entering and leaving such tenuous cloud.

Throughout the flight conditions were smooth and stable, there being about 1 okta medium cloud and 8 oktas low cloud south of a line Birmingham–Swansea. The corrected air temperature at 45,000 ft. was −56°C. throughout the flight.

I have never before seen cloud above 42,000 ft. in this country while flight-testing to altitudes of 50,000 ft. over the last three years.

Synoptic situation.—The synoptic situation was such that a depression in mid Atlantic at 1200 G.M.T. on August 10 was expected to move rapidly eastwards. There was a very large mass of warm air to the south of it and the occlusion of this air was expected to lead to prolonged rainfall over much of the British Isles, heavy in places. This in fact happened.

Upper air charts on the 10th at the relevant time showed a warm ridge on the Atlantic and a cold trough over the North Sea extending southwards to France, with a north-north-westerly air stream over the British Isles. In this stream the maximum wind was 340° 90 kt. at about 250 mb. (34,000 ft.) from

Aldergrove to Lyme Bay. The tropopause was at 37,000–40,000 ft. with an inversion to 40,000–44,000 ft., decreasing above these levels to an almost isothermal lapse rate. The wind at 45,000 ft. was 340° 30 kt., and at 50,000 ft. 340° 15–20 kt.

Stations in England were asked to keep watch for very high cloud on the evening of the 10th, and at 1910 G.M.T. Hullavington reported 6 or 8 streaks of cloud which appeared very high and like condensation trails. This cloud appeared south-east of the station behind some altocumulus by which it was finally occluded. This cloud was described as "not feathery like cirrus, but quite dense, an unusual type of cloud not previously observed". It was also observed at Benson.

Centenary of the Austrian Zentralanstalt für Meteorologie und Geodynamik

The Austrian Zentralanstalt für Meteorologie und Geodynamik celebrated its centenary from September 20 to 26, 1951.

The Anstalt was founded by Imperial Decree on July 23, 1851, and placed under the Directorship of Carl Kreil, a meteorologist and astronomer of Prague, who had, in 1848, put forward to the Austrian Academy of Sciences a plan for the foundation of a meteorological and magnetic service.

The roll of Directors of the Zentralanstalt runs:—

Carl Kreil, 1851–1862
Carl Jelinek, 1863–1876
Julius von Hann, 1877–1897
Josef Maria Pernter, 1897–1908
Wilhelm Trabert, 1909–1915
Felix Exner, 1916–1930
Wilhelm Schmidt, 1930–36
Heinrich Ficker, 1937–

The Director has always also held the Chair for Geophysics at the University of Vienna.

Jelinek is well remembered for his psychrometric tables. During his period of office the first International Congress of Meteorologists was held in Vienna.

Hann founded the Sonnblick Observatory and wrote the very well known textbooks "Handbuch der Klimatologie" and "Lehrbuch der Meteorologie".

Pernter re-organized the Zentralanstalt and particularly developed its work in synoptic meteorology. He published in 1901 a work on atmospheric optics which, as later enlarged and revised by his successor Exner, is now the standard work on the subject.

Trabert was particularly eminent as an inspiring Professor of Meteorology. He recognized early the importance of Margules's work on the "Energy of storms".

Exner is best known to British meteorologists as the author of a textbook, "Dynamische Meteorologie", for long unique in its field. He had a particularly heavy task of re-organization in very difficult economic circumstances after the first world war.

Schmidt was one of the founders of the study of turbulence in meteorology. His term "Austausch" for the turbulent process is widely used.

No historical note on the Zentralanstalt can omit the name of Max Margules, pioneer in the study of the transformation of potential and thermal energy into kinetic energy in the atmosphere. He was a member of the staff from 1882 to 1906.

Cumulonimbus clouds over Lake Victoria

The area around the north-western shores of Lake Victoria has a greater rainfall than the rest of British East Africa, and no month is a dry one although the maximum rainfall occurs in the period March to May. Consequently the vegetation in the area is always green and the land is capable of supporting a large native population. A considerable portion of the rainfall is associated with cumulonimbus clouds and thunderstorms which form over the lake during the late afternoon or evening and which persist well into the night, especially over the north-west corner of the lake and its associated islands. The photographs facing pp. 348 and 349 show typical cumulonimbus clouds over the the north-western shores of the lake on November 18, 1941, at 1530, taken looking north from a steamer sailing from Bukoba to Entebbe. The photographs overlap slightly, the photograph facing p. 348 being to the left of that facing p. 349.

REVIEW

Hugh Robert Mill. An Autobiography. By Hugh Robert Mill. 8¾ in. × 5¾ in., *Illus.* pp. xii+224. Longmans, Green and Co. London, New York, Toronto, 1951. Price: 18*s.*

This book is the outcome of a suggestion made in 1941 by the President of the Royal Meteorological Society that Dr. Mill should write some reminiscences of his connexion with the Society. These reminiscences have been extended, and in the book separate chapters are devoted to the various facets of Dr. Mill's extensive and varied experiences as a geographer, meteorologist, author and traveller. The chapters are headed (1) Forebears (2) The lure of chemistry (3) The call of the sea (4) The use of words (5) The revival of geography (6) The distribution of rain (7) The attraction of the Poles and (8) Holiday travel. "My intention was to conclude with a synthesis of these eight into one personality—myself as a whole. I had thought of calling the book *My nine lives*, but they would not have been in reality nine lives, but one life composed of a number of closely woven strands, like the log-line used for a patent log to measure the speed of a ship, not merely twisted together loosely like a piece of string." Publication was arranged by Prof. Dudley Stamp, who contributes both the Introduction and Postscript.

One of the attractions of the book is the short, vivid sketches of the great personalities Mill met during his long life, 1861–1950. His encyclopaedic knowledge of polar exploration caused him to be sought out by polar explorers; he met the leading geographers and meteorologists both in this country and abroad, and as the rainfall expert of this country he had personal contacts with many rainfall observers and the leading water-engineers.

The book should have a wide appeal. The geographer will be interested in the historical account of the attempts to secure for geography its true place as a science, the rainfall observer in the account of the development of our knowledge of the rainfall of the British Isles, and the more adventurous in the fascinating details, and troubles, of polar exploration. An autobiography by the author of "The realm of nature", "The siege of the South Pole" and "Life of Sir Ernest Shackleton", amongst other works, should also be read as a literary effort. "His words, like so many nimble and airy servitors, trip about him at command." The philosopher, too, might well find much to reflect upon. "In one respect I occupy a position of exceptional advantage. The detailed and unbroken record of my daily doings gives me a vantage point for retrospect. On looking backward, I can answer the question: 'a good thing or a bad thing, Life is which?' My answer to this, taking account of the ups and downs, rights secured and wrong endured, joys and sorrows, is that it is in the main *Good.*"

When the volume comes to be reprinted it would be useful to add the page reference (p. 124) in the index under Sir Napier Shaw and to correct the date given in Appendix I (p. 216) of the Bruton rain of 9·56 in., which should be June 28, 1917, as on p. 129.

J. GLASSPOOLE

ERRATA

October, 1951, PAGE 304, lines 10–12; *for* "This is in itself . . . . .realm of macroclimate." *read* "This in itself is the essential first step to obtain knowledge of the macroclimate. The present book is an unsurpassed attempt to make further steps towards a complete knowledge of the more real and vital realm of microclimate."

November, 1951, PAGE 337, line 3; *for* "facing p. 316" *read* "facing p. 317"; line 9; *for* "facing p. 317" *read* "facing p. 316".

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—For the flight of T.R.H. The Princess Elizabeth and The Duke of Edinburgh to Canada on Monday, October 8, 1951, ocean weather ships stationed in the North Atlantic Ocean stood by at immediate readiness. The Master of the *Weather Observer* in reporting on the voyage which covered this flight stated that, after more than a fortnight's good weather, continuous gale, which set in on October 11, was experienced during the last eight days of the voyage. The wind was force 12 and a sudden veer gave the worst sea for confusion which he had seen in four years on the station. The ship's motion was extremely violent.

Amusement—and consternation—was caused by an incident in the *Weather Observer* during the 1400 G.M.T. ascent on September 29, 1951. Immediately after the launch, the radio-sonde operator, retuning the receiver to pick up the transmitter's signal, was astonished to find the transmitter apparently emitting the strains of a cinema organ. A hurried conference with the W/T staff revealed that the music was part of the B.B.C. Home Service, on a new wave-length near the radio-sonde band, and that the transmitter was silent. The ascent was repeated—without incidental music.

Long-distance balloon competition.—One of the attractions at Gibraltar on Battle of Britain Day was a long-distance balloon competition organized by the staff of the Meteorological Office there. Competitors paid sixpence for a hydrogen-filled balloon to which was attached a stamped postcard addressed to the Office with instructions in Spanish to the finder. A first prize of £3 was offered to the sender of the balloon which travelled farthest on the evidence of the postcards returned by September 30, and small prizes for all balloons found outside a 100-Km. circle centred on Gibraltar. A prize of 17*s.* went to the finder of the postcard attached to the winning balloon. A gaily coloured stall displayed large notices giving the rules of the competition and a map showing the 100-Km. circle. After a slow start, the appearance of a few balloons drifting slowly away attracted crowds to the stall, and so busy were the balloon sellers that they had little opportunity to watch the spectacular flying display which was in progress most of the afternoon. Eventually all the balloons were sold and the sum taken covered all expenses and left a handsome profit to be handed to the Royal Air Force Benevolent Fund.

The wind varied from 080° 8 kt. at the surface to 040° 12 kt. at 10,000 ft. and 320° 12 kt. at 18,000 ft. The rate of ascent of the balloons was anything between 50 and 500 ft./min. as no attempt had been made to fill them uniformly. By the closing date 30 postcards had been returned, nine from North Africa, two from the southernmost point of Spain and the remainder from Algeciras and Los Barrios across the Bay of Gibraltar. The winning postcard was found near Tangier Airport. A few days after the closing date a batch of 5 postcards was received from a village 24 miles south-west from Tetuan, the capital of Spanish Morocco; some enterprising competitor had apparently tied several balloons together.

There were two rather remarkable coincidences in the results: two balloons released by a Gibraltar policeman were found in different parts of Algeciras by different people living at the same address; and three of the balloons returned from Africa had been released by the Senior Meteorological Officer and members of his family.

The event, the first of its kind in Gibraltar, roused considerable interest in the local press and amongst the general public.

Transfer of staff to Colonial Meteorological and other Services.—One officer and seven more Assistants have left for service in the Falkland Islands, namely Mr. S. D. Glassey, and Messrs. R. A. Berry, F. Burns, B. J. Ellis, D. S. Hosie, F. L. Johnson, B. Kemp and D. McCallum.

Mr. J. F. Fisher has been appointed Meteorological Officer in the new service in Nyasaland, and Mr. K. R. Chaplin has joined the other Assistants who have gone to serve under Mr. J. E. Stevens in Northern Rhodesia.

Mr. D. V. Field and Messrs. D. F. J. Brebner and A. J. Bunting were selected for some special work with the Institute of Aviation Medicine.

Retirement.—Miss D. R. M. Figgins retired from the Meteorological Office on October 31, 1951, because of ill health.

Since she joined the Office on November 19, 1917, Miss Figgins has worked in the British Climatological Branch. Her main responsibility has been to ensure that voluntary climatological observers had everything necessary to maintain their records whether the need was for forms, instruments or guidance. She took a keen interest in this work and acquired a vast store of knowledge about climatological stations past and present and of the data they had provided. This knowledge she used to great advantage in answering inquiries. Her job has demanded minute attention to a multiplicity of detail and might have proved a burden to some but not to Miss Figgins, with her unusually good memory and capacity for rapid working. Among her other duties Miss Figgins has on several occasions included the sub-editing of this Magazine.

We know that Miss Figgins leaves her post with regret and her colleagues share that regret while wishing her a renewal of health in retirement.

Sports.—*Swimming.*—We offer congratulations to Mr. S. W. Lewis who won the free-style and breast-stroke Air Ministry championships, and to Mr. G. Goodger and Mr. R. Nuttall who were second and third respectively in the free-style; also to Miss Barbara Davies who won the Air Ministry Ladies Swimming Championship for the third successive year.

The Meteorological Office Relay Teams gained the first two places in the Air Ministry Relay Championship, an excellent performance. This is the third year running that the Office has won the Allen Fiddes Trophy which, alas, is missing and cannot be traced.

Christmas Party.—The Social and Sports Committee announce that a Christmas Party (tickets 1*s.* 6*d.* each) will be held on December 18 in the Air Ministry Refreshment Club, "B" Block, Adastral House, from 6.30 to 10.30 p.m. Like last year's party which was so successful it will be an informal occasion with music, dancing and games.

[The balloons referred to in the paragraph on the Gibraltar competition were not from Meteorological Office stocks.—Ed. *M.M.*]

NOTICE

Price of the Meteorological Magazine

It is regretted that because of increases in the cost of paper and printing it has become necessary to increase the price of the *Meteorological Magazine* to 2*s.* with effect from the January 1952 number.

The net annual subscription will become £1. 5*s.* 0*d.*, including postage.

Present subscribers will remain on the existing rate until renewal of their subscription falls due.

WEATHER OF OCTOBER 1951

Mean pressure exceeded 1020 mb. over central Europe and Scandinavia and reached 1028 mb. in places in eastern Europe. Mean pressure lying between 1015 and 1020 mb. extended over large areas including west Europe, the British Isles, the North Atlantic south of latitude 45°N. and the greater part of North America. Mean pressure was below 1015 mb. over the central Mediterranean and fell to 1005 mb. westwards and northwards of the British Isles. The lowest mean pressure, 997 mb., was in the region south-west of Iceland, about latitude 60°N.

Mean pressure was above normal over Europe, the excess generally amounting to 10–13 mb. over southern Scandinavia. The greatest deficit of mean pressure of 5–8 mb. below normal occurred south-west of Iceland.

Mean temperature was between 40° and 50°F. over Scandinavia and east Europe, 50–60°F. over west Europe, 60–70°F over the Mediterranean and 70–85°F. over west Africa. Mean temperature was generally 5°F. above normal over Scandinavia but about 2–4°F. below normal over the rest of Europe.

In the British Isles the weather was, on the whole, dry, sunny and quiet, with rather frequent fog at night and in the early morning, particularly in England. Mean temperature exceeded the average in the west and north.

In the opening days of the month an anticyclone was situated over Scandinavia, and subsequently it moved to the southern Baltic. This system maintained dry weather over much of the country until the 12th, though troughs of low pressure associated with depressions in the Atlantic caused rain at times in the west, for example on the 3rd, 4th, 8th and 9th (on the 9th 1·73 in. of rain was registered at Duntuilm and 1·42 in. at Tiree). Fog, mostly at night and in the early morning, was fairly widespread in England from the 4th to the 16th, while ground frost was recorded locally in Great Britain from the 8th to the 12th and was widely registered in England on the 12th. Less settled conditions set in on the 12th, when a trough of low pressure moved across England from south-west of Ireland; rather heavy rain fell in south-west Ireland and the Scilly Isles on the 12th and slight rain in England on the 13th. On the 14th and 15th another trough caused rain in the west and north; meanwhile widespread fog developed over England at night and in the early morning. On the 16th a trough, associated with a small secondary south of Iceland, moved across the British Isles; gales occurred in the north of Scotland and rain was recorded in many places but it was slight except locally in west and north Scotland. From the 19th to the 21st a deep depression over Iceland moved slowly south and turned east to a position near the Shetlands; rain or showers occurred and local thunderstorms, but there were also long bright periods. The depression subsequently moved away north-north-east. Temperature fell considerably with the influx of cold air behind the depression, and showers of rain, sleet, hail or snow and local thunderstorms occurred. The 22nd was the coldest day of the month in most places, the maximum temperature failing to reach 45°F. at numerous stations. From the 23rd to the 26th an anticyclone moved from south-west of Ireland across the southern districts of the British Isles to Germany; dry, frosty, mainly sunny weather, apart from morning fog, returned to England but some rain occurred in west and north Scotland on the 23rd and 24th. Low minimum temperatures in the screen included 20°F. at Eskdalemuir and 24°F. at Silloth on the 23rd, 23°F. at Bristol on the 24th and 25°F. at Elmdon and Shawbury on the 25th. On the 27th a depression moved quickly from south-westward of Iceland to the south-west of Ireland and later across England and Wales to the North Sea. Appreciable rain fell in parts of Ireland and south-west England on the 27th and more general rain on the 28th and 29th. On the 30th and 31st a shallow depression moving south-east from Iceland to the North Sea gave renewed rain and local thunderstorms.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Per-centage of average	No. of days difference from average	Per-centage of average
	°F.	°F.	°F.	%		%
England and Wales ...	72	19	−0·2	31	−10	111
Scotland	69	19	+2·1	42	−9	104
Northern Ireland ...	68	31	+2·1	37	−8	100

RAINFALL OF OCTOBER 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent of A
London	Camden Square ...	·91	35	*Glam.*	Cardiff, Penylan ...	1·91	4
Kent	Folkestone, Cherry Gdn.	3·21	80	*Pemb.*	Tenby	1·67	3
,,	Edenbridge, Falconhurst	1·25	35	*Card.*	Aberdovey (Plas Penhelig)	1·20	2
Sussex	Compton, Compton Ho.	1·54	34	*Radnor*	Tyrmynydd	1·53	2
,,	Worthing, Beach Ho. Pk.	1·37	38	*Mont.*	Lake Vyrnwy	1·89	3
Hants.	Ventnor, Cemetery ...	1·61	40	*Mer.*	Blaenau Festiniog ...	2·23	2
,,	Bournemouth	1·66	39	*Carn.*	Llandudno	·92	2
,,	Sherborne St. John ...	·92	26	*Angl.*	Llanerchymedd ...	·70	1
Herts.	Royston, Therfield Rec.	·75	28	*I. Man*	Douglas, Borough Cem.	·88	1
Bucks.	Slough, Upton	·95	34	*Wigtown*	Port William, Monreith	...	..
Oxford	Oxford, Radcliffe ...	·89	31	*Dumf.*	Dumfries, Crichton R.I.	·25	
N'hants.	Wellingboro', Swanspool	·68	27	,,	Eskdalemuir Obsy. ...	·46	
Essex	Shoeburyness	1·24	53	*Roxb.*	Kelso, Floors	·32	1
,,	Dovercourt	·78	33	*Peebles*	Stobo Castle	·58	1
Suffolk	Lowestoft Sec. School ...	·56	20	*Berwick*	Marchmont House ...	·46	1
,,	Bury St. Ed., Westley H.	·89	33	*E. Loth.*	North Berwick Res. ...	·24	
Norfolk	Sandringham Ho. Gdns.	1·06	35	*Midl'n.*	Edinburgh, Blackf'd. H.	·52	1
Wilts.	Aldbourne	·67	20	*Lanark*	Hamilton W. W., T'nhill	·86	2
Dorset	Creech Grange... ...	1·63	32	*Ayr*	Colmonell, Knockdolian	1·04	2
,,	Beaminster, East St. ...	·82	18	,,	Glen Afton, Ayr San. ...	...	...
Devon	Teignmouth, Den Gdns.	·71	18	*Bute*	Rothesay, Ardencraig ...	2·28	52
,,	Cullompton	1·32	32	*Argyll*	Morvern, Drimnin ...	3·28	55
,,	Ilfracombe	1·49	33	,,	Poltalloch	3·42	69
,,	Okehampton, Uplands	1·53	25	,,	Inveraray Castle ...	3·52	50
Cornwall	Bude, School House ...	1·76	43	,,	Islay, Eallabus	2·27	48
,,	Penzance, Morrab Gdns.	2·39	51	,,	Tiree	3·87	85
,,	St. Austell	2·01	38	*Kinross*	Loch Leven Sluice ...	·59	17
,,	Scilly, Tresco Abbey ...	1·42	37	*Fife*	Leuchars Airfield ...	·19	7
Glos.	Cirencester	1·02	31	*Perth*	Loch Dhu	2·29	32
Salop	Church Stretton ...	1·25	34	,,	Crieff, Strathearn Hyd.	·86	22
,,	Shrewsbury, Monkmore	·81	29	,,	Pitlochry, Fincastle ...	1·35	41
Worcs.	Malvern, Free Library	1·04	35	*Angus*	Montrose, Sunnyside ...	·73	26
Warwick	Birmingham, Edgbaston	·72	26	*Aberd.*	Braemar	1·10	29
Leics.	Thornton Reservoir ...	·70	25	,,	Dyce, Craibstone ...	·91	27
Lincs.	Boston, Skirbeck ...	·87	32	,,	Fyvie Castle	1·53	40
,,	Skegness, Marine Gdns.	...	...	*Moray*	Gordon Castle	1·34	42
Notts.	Mansfield, Carr Bank ...	·76	25	*Nairn*	Nairn, Achareidh ...	1·34	
Derby	Buxton, Terrace Slopes	1·20	24	*Inverness*	Loch Ness, Garthbeg ...	1·59	
Ches.	Bidston Observatory ...	·75	23	,,	Glenquoich	4·60	
Lancs.	Manchester, Whit. Park	1·27	39	,,	Fort William, Teviot ...	3·63	5
,,	Stonyhurst College ...	1·27	28	,,	Skye, Duntuilm ...	6·68	12
,,	Squires Gate	1·65	47	*R. & C.*	Tain, Tarlogie House ...	1·13	
Yorks.	Wakefield, Clarence Pk.	·80	28	,,	Inverbroom, Glackour ...	3·27	
,,	Hull, Pearson Park ...	·95	32	,,	Applecross Gardens ...	5·03	84
,,	Felixkirk, Mt. St. John	1·59	55	,,	Achnashellach	4·70	
,,	York Museum	1·70	63	,,	Stornoway Airfield ...	3·39	69
,,	Scarborough	·86	27	*Suth.*	Loch More, Achfary ...	...	...
,,	Middlesbrough... ...	1·34	45	*Caith.*	Wick Airfield	1·91	65
,,	Baldersdale, Hury Res.	·89	22	*Shetland*	Lerwick Observatory ...	2·48	63
Norl'd.	Newcastle, Leazes Pk....	·77	25	*Ferm.*	Crom Castle	1·14	35
,,	Bellingham, High Green	1·03	26	*Armagh*	Armagh Observatory ...	·85	31
,,	Lilburn Tower Gdns. ...	·76	21	*Down*	Seaforde	·51	14
Cumb.	Geltsdale	1·40	38	*Antrim*	Aldergrove Airfield ...	·75	25
,,	Keswick, High Hill ...	1·14	20	,,	Ballymena, Harryville...	1·34	36
,,	Ravenglass, The Grove	·84	19	*L'derry*	Garvagh, Moneydig ...	1·61	46
Mon.	Abergavenny, Larchfield	·99	24	,,	Londonderry, Creggan	2·08	57
Glam.	Ystalyfera, Wern House	1·71	25	*Tyrone*	Omagh, Edenfel ...	1·89	51